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Sorensen
POWER SUPPLIES

instruction manual for MODEL DCR 20-250A

MP MASTER
MA25402

SORENSEN COMPANY

A UNIT OF RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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SORENSEN COMPANY

Manual No.
14-6240

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SECTION I
INTRODUCTION AND DESCRIPTION

1-1. INTRODUCTION.

1-2. This manual contains operation and maintenance data on the Model DCR20-250A, three-phase input power supply, manufactured by Raytheon Company, Sorensen Operation, Manchester, N.H. It is intended to familiarize the user with the functioning of the unit, to introduce the varied applications for which the unit may be adapted and to furnish sufficient maintenance data to assure long operating life.

1-3. Seven sections comprise the major subdivisions. This introduction and a general description of the unit and its applications, along with complete unit specifications and performance curves, form Section I. Section II delineates procedures to be followed when the unit arrives at destination. It also contains procedures for adapting the unit to its alternate input voltages. A tabular listing of front-panel indicators and controls, and a functional description of each item completes Section III. Operating instructions, including procedures for adapting the unit to a number of varied applications, are outlined in Section IV. Section V provides the principles of operation. Details on troubleshooting, repair and calibration of the unit are furnished in Section VI. An illustrated replacement parts list forms Section VII.

1-4. DESCRIPTION.

1-5. Designed for either rack or floor mounting, the Model DCR20-250A power supply provides a stable, highly regulated dc output from a wide range of three phase input voltages and frequencies. Voltage and current ranges are 0-20 V and 0-250A (at 55°C (121°F)), respectively. (For complete unit specifications, refer to Table 1-1). The unit exhibits excellent transient response as well as low ripple in both the voltage-regulating and current-limiting modes. Turn-off and turn-on overshoots above 2 V (output setting) are nonexistent and below this voltage are only 0.3 volts.

1-6. Other designed-in features include provisions for adapting the unit for remote programming, remote sensing and series and parallel operation. Increased versatility is also obtained by the floating neutral, which permits either a three-or four-wire input.

1-7. AUTOMATIC CROSSOVER. The automatic-crossover system allows the unit to transfer operating modes as a function of load requirements. If, for example, current output is set for 100 A and the load requirements are greater than this value, the unit will transfer operation automatically from voltage regulating to the

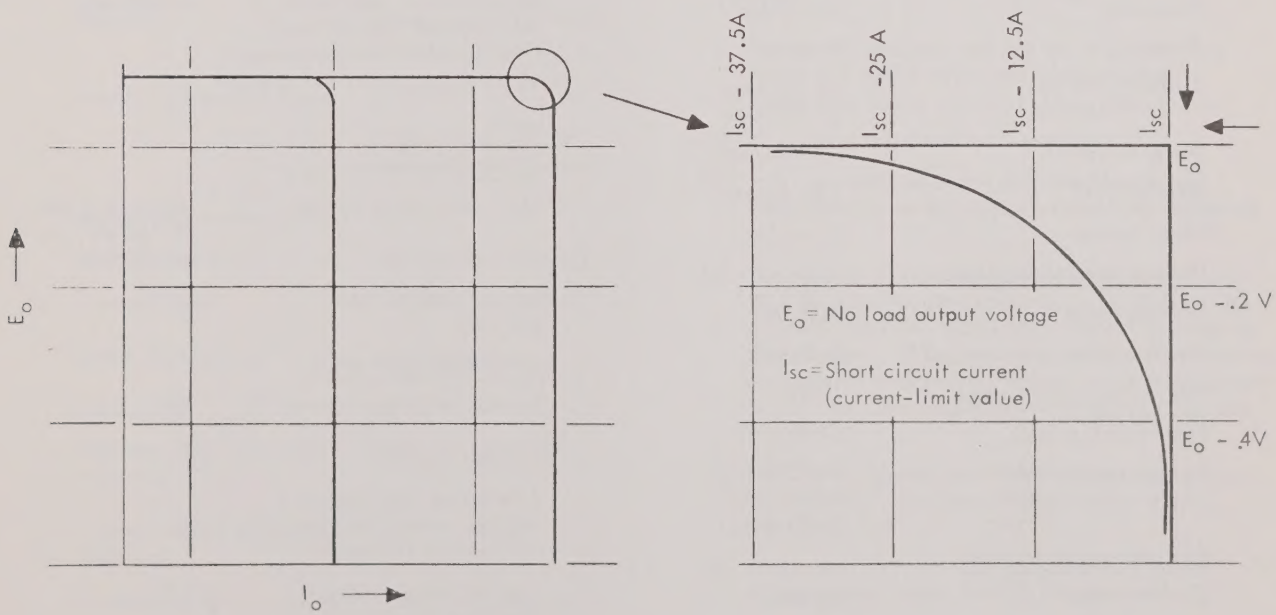


Figure 1-1. Crossover Characteristics.

current-limiting mode. In this mode, the current will be held to the 100 A selected output. If load requirements are lowered or if the current-limiting value is raised through the front-panel-mounted current adjust control, transfer to the voltage-regulating mode will occur automatically.

1-8. REMOTE PROGRAMMING. The unit may be remote programmed in any of three modes, voltage, current or resistance. This feature permits the user to adjust the output voltage or current to preset values from remote locations.

1-9. REMOTE SENSING. To allow for voltage drops in the load lines, a remote-sensing system has been designed into the power supply. This system monitors the unit output voltage to assure that the selected voltage is being delivered to the load and not simply across the unit's output terminals. The maximum drop for which the unit will compensate is 3 V per line.

1-10. SERIES OPERATION. Some applications require a higher output voltage than that for which the unit is designed. To meet the demands of these applications, the unit incorporates provisions for adaptation to series operation. As many as 5 units may be placed in series to provide up to 100 volts output.

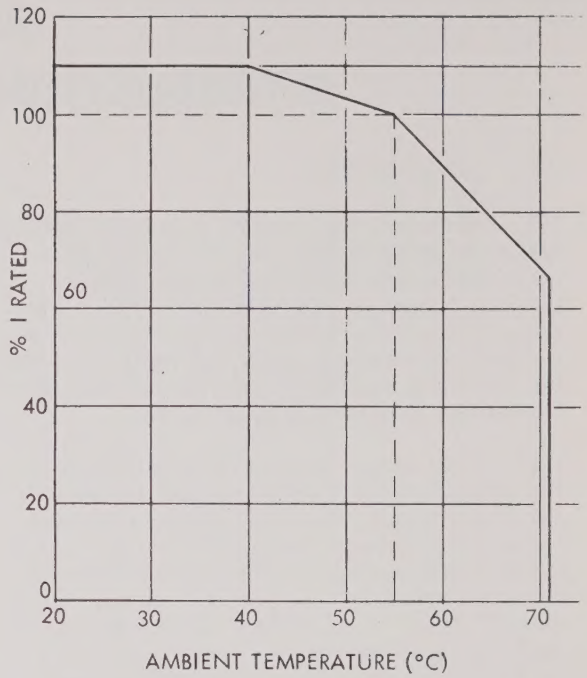


Figure 1-2. Current Derating Characteristics

Table 1-1. Unit Specifications.

ELECTRICAL	
Input Ratings:	
Voltage Range	187-229 Vac 207-253 Vac
Frequency	50-63 Hz(1)
Phase	Three
Current 208 Vac 230 Vac	36.5 A max. 37.0 A max.
Power factor (2)	0.60 typical
Efficiency(2)	72% typical
Output Ratings:	
Voltage Regulation Mode	
Voltage range	0-20 Vdc
Coarse voltage adjust range(3)	0-20 Vdc
Fine voltage adjust range	1 Vdc
Resolution (typical)	10 mV
Current range at 40°C 55°C 71°C	0-275.0 Adc 0-250.0 Adc 0-165.0 Adc
Current Regulation Mode	
Current range	see above
Typical resolution	1250 mA
Dynamic voltage range(4)	0-19 Vdc
Current-Voltage Crossover	see Figure 1-1
Regulation:	
Output voltage regulation (for combined line and load)	± 0.10% or ± 8 mV, whichever is greater
Output current regulation for combined line and load (full dynamic voltage change) with voltage control set to 40 V	± 500 mA
Ripple:	
Voltage Regulation Mode	
Max. RMS ripple voltage	60 mV ± 0.8% E_o or 160 mV, whichever is less
Typical peak-to-peak less than	3 V
Current Regulation Mode	
Typical RMS ripple current (5)	2%
Transient Response:	
(for a step load change of 1/2 load to full load, or full load to 1/2 load)	
Typical output-voltage deviation	1 V
Typical recovery to within ± 1% of band	40 msec.

1-11. PARALLEL OPERATION. Like series operation, parallel operation permits the unit to be used in applications where output requirements are above those for which the unit is designed. As many units as desired may be placed in parallel. However, some loss of regulation will be incurred for each unit (refer to para. 4-31).

1-12. FAILURE PROTECTION. In addition to the current-limiting protection provided by automatic crossover and the current regulator, the unit incorporates two other protection systems. One drops the unit output to zero and energizes a light on the control panel if there is a loss of one input phase. The other, thermal overload usually resulting from a cooling-fan failure, will also drop the output, and a failure indicator on the panel will glow.

1-13. OPTIONAL EQUIPMENT.

1-14. AUXILIARY CHASSIS. A three-phase autotransformer is offered as an optional item to increase the unit's already wide flexibility. With this accessory, three-phase inputs of 342-418 V, 390-440 V, or 414-506 V may be used. The transformer is installed in a specially designed chassis so that, if desired, the chassis may be mounted to the DCR supply. Leading particulars on the transformer are listed in Table 1-2.

1-15. REAR SUPPORT KIT. This kit is comprised of two angle brackets which, when rack-mounting a unit, are installed on the vertical members of the rack to guarantee adequate support.

1-16. CASTER KIT. This optional item, when installed, allows the unit to be moved easily from place-to-place. It consists of four swivel-type casters, two of which have braking mechanisms.

1-17. COVER KIT. A kit designed to add to the decorative appearance of the unit is offered as an accessory. It includes two side covers and the required attaching hardware.

Table 1-1. Unit Specifications (Cont.).

Temperature Coefficient:	
Voltage Regulation Mode	
Output Voltage	8 mV/°C (typ.)
Current Regulation Mode	
Output Current	500 mA/°C (typ.)
Output Voltage Overshoot:	
Turn off	none above 2 V; 0.3 V below 2 V (typ.)
Turn on	none above 2V; 0.3 V below 2 V (typ.)
Ambient temperature range:	0-71°C (see Figure 1-2 for current derating curve)
Remote Programming:	
Voltage mode (6)	160 ohm/V (typical)
Current mode	0.6 ohm/A (typical)
Output Impedance:	see Figure 1-3
Stability:	
Voltage mode (8 hr after warm-up)	0.01 V (typical)
Current mode (8 hr after warm-up)	0.5 A (typical)
Remote Sensing:	Max. 3 V drop in each leg
Cooling:	Forced air
Suppression:	RFI suppressed (7)

MECHANICAL

Dimensions:	
Width	19 in.
Height(8)	18.25 in.
Depth	22 in.
Rack-mtg. height	17.5 in.
Weight:	318 lbs.

(1) Ripple and transient response are degraded by a factor of $(60/f)^2$ when unit is operated at frequencies below 60 Hz (f is line frequency).

(2) At nominal input and full rated output

(3) It is recommended that a 0.5 ohm bleeder be connected across the output terminals for operation below 1 V.

(4) The dynamic voltage range may be extended to 0-20 V by adjusting no-load voltage to 22.0 V. Use COARSE and FINE VOLTAGE ADJUST controls for this purpose. If these are not sufficiently effective, use internal resistor R39, noting that any adjustment of R39 may alter zero-output-voltage setting. See Figure 1-1.

(5) RMS ripple current specified is for dynamic range of 2.85-19 V. For specifications below 2.85 V, see Figure 1-4

(6) Programming current is approximately 2 mA in voltage mode; about 3 mA in current mode

(7) Within 15 dB of MIL-I-26600 and MIL-I-6181D

(8) Height over feet

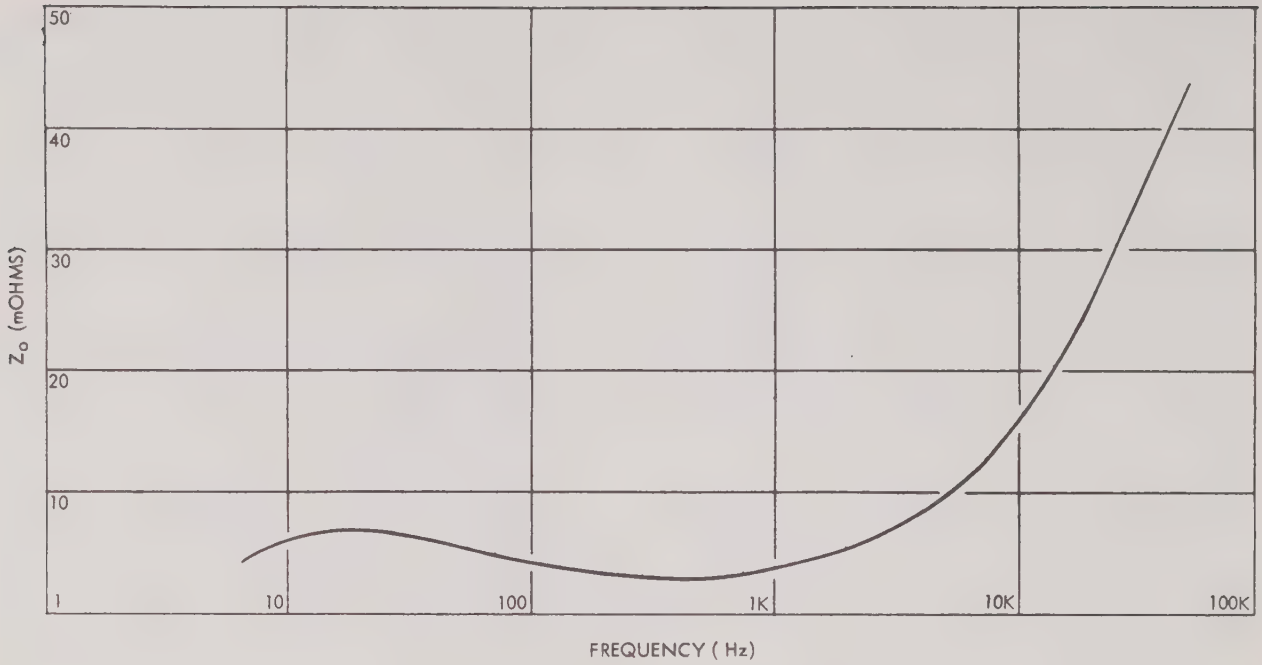


Figure 1-3. Typical Output Impedance (Semilog Plot).

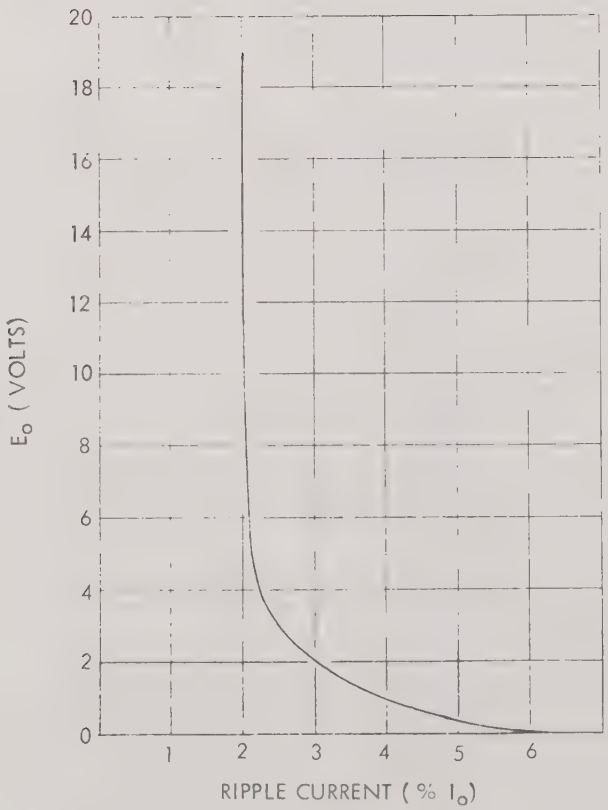


Figure 1-4.
Ripple Current Vs. Output Voltage.

ITEM	PART NO.	DESCRIPTION
Auxiliary Chassis	195-2144 Model ST-101	3 phase autotransformer Input Voltage: 380 V/50-63 Hz input 415 V/50-63 Hz input 460 V/50-63 Hz input Input Current: 380 V 22 A max. 415 V 22 A max. 460 V 19 A max. Output Voltage: 187-229 V AC (380 V input) 207-253 V AC (415 or 460 V input) Output Current Range: 0-37 Aac Cooling: Convection Dimensions: Width: 19 in. Height: 7 in. Depth: 22 in.
Support Kit	190-3674	Heavy-duty angle brackets to help support rack mounted units.
Caster Kit	190-3675	Four casters to give unit mobility. Two support brackets. 16 screws and washers.
Cover Kit	190-3677* 190-3679*	Two side covers for decorative purposes. 8 to 16 screws.

* Kit 190-3677 is for units without auxiliary chassis; for units with auxiliary chassis, use Kit 190-3679.

Table 1-2. Optional Equipment.

SECTION II

PREPARATION FOR USE

2-1. GENERAL.

2-2. After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that the unit is in good working order. These consist basically of visually checking for damaged parts or components and of making some electrical checks.

2-3. INSPECTION.

2-4. Proceed as follows to inspect for damage incurred during shipment:

a. Check meter faces for cracked or broken glass. Check each meter pointer for zero indication. Use zero adjust to bring indicator to zero, if necessary.
b. Look for cracked or broken lenses on the indicating lights.
c. Rotate the FINE and COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS potentiometers. Knobs should turn smoothly through a 300-degree angle.
d. Test for positive action of circuit breaker by operating a few times. Set breaker to OFF position.

2-4. (Cont.)

e. Remove six front-panel retaining screws, and gently separate panel a few inches from chassis to allow internal inspection. Then, check tightness of screw-type connections at the transformer and silicon-controlled rectifier board. Reinstall panel using screws originally removed.

f. Detach side panels, and inspect for loose connections and structural damage. Remove all packing material.

g. Remove right-hand, rear panel, and inspect for loose connections. Make sure that the links connected between terminals 1-2 and 3-4 on terminal board (TB2), located at the upper left-hand side of the vertical panel, are securely fastened. Reinstall panel.

2-5. If any optional equipment (refer to Table 1-2) has been purchased with the unit, assure that all parts are accounted for and that no damage has been incurred in shipment. (Optional parts are normally shipped loose in the packaging carton.)

2-6. OPTIONAL EQUIPMENT INSTALLATION.

2-7. The unit is shipped in a ready-to-use state. However, if optional accessories have been purchased, they must be installed at destination. The following paragraphs, therefore, delineate accessory installation.

2-8. AUXILIARY CHASSIS. The auxiliary chassis may be mounted below the main unit chassis or it may be remotely located, if so desired. To mount the chassis, proceed as follows:

NOTE

The following procedures would be facilitated if an overhead lifting device of sufficient capacity to raise and hold the unit, while mounting the chassis, were available.

a. Remove front and rear panels on auxiliary chassis. Mounting hardware is located on either side of panels.
b. Remove bag from right-hand handle, and remove two spacers and screws from bag.
c. Using the eye hooks at the top of the unit and an overhead lifting device, raise the unit about 10 inches from the floor.
d. Detach feet from bottom of main unit and reinstall beneath auxiliary chassis.
e. Place one spacer on the forward bracket which runs laterally across the top of the unit and align the holes in both spacer and bracket. Repeat procedure for other spacer and bracket at rear of unit.
f. Insert one screw up through a bracket and spacer, and then use the screw as a hole-aligning guide when lowering the main chassis onto the auxiliary chassis.
g. Secure chassis with screws provided.

2-9. CASTER KIT. Install the casters as follows:

a. Raise the unit off the floor until the feet are sufficiently exposed to enable removal; then detach feet.
b. Mount casters to support brackets and align brackets over holes vacated by feet. Attach with hardware provided.

NOTE

The two casters with braking mechanisms are to be mounted over the forward holes.

2-10. SUPPORT KIT. Mount the left- and right-hand angle brackets to the rear vertical rack channels at an elevation which insures cradling of the unit.

2-11. MECHANICAL INSTALLATION.

2-12. The unit is shipped ready for floor use. However, if it is to be rack mounted, eye hooks at the top of the unit and feet below must be removed. Due to the unit's relatively large mass, it should be inserted into a slot at or near the bottom of the rack. If one of the three-phase inputs other than 208 V is to be used, it may be easier to make the necessary wiring changes prior to installing the unit (refer to para 2-14 through 2-19).

2-13. ELECTRICAL INSTALLATION.

2-14. The unit is shipped wired to accept a 208 V three phase input. If either a 230, 380, 415 or 460 volt input is to be used, minor alterations must be made to the transformer wiring.

NOTE

An auxiliary chassis (refer to Table 1-2) must be used if the unit is to accept either 380, 415 or 460 volt input.

CAUTION

Unit is phase-rotation sensitive. Test input phase-rotation per para 2-23.

2-15. 208 VOLT INPUT. For a 208-volt input, simply connect the input leads to terminals 1, 2, 3 (and GRD for a four-wire input) on terminal board TB1 (INPUT) located at the bottom center of the rear panel. See CAUTION note following para 2-14.

2-16. 230-VOLT INPUT. To adapt unit for a 230-volt input, simply disconnect the yellow wire at tap 3 of transformer T5 (located immediately above terminal board TB1 (INPUT) on the rear panel) and reconnect at tap 4 of the same transformer. Then, connect input leads to terminal board TB1. For four wire unit, connect neutral to ground (GRD) terminal. See Figure 2-1 for tapping arrangement. Refer to CAUTION note following para 2-14.

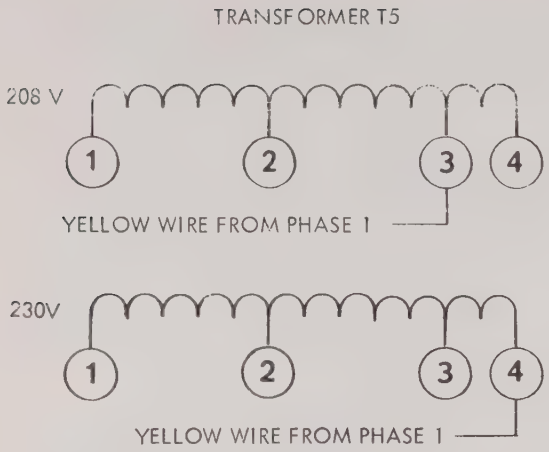


Figure 2-1. Unit Input Connections.

2-17. 460 VOLT OPERATION. The unit is not designed to accept other than 208 or 230 volt inputs. However, the optional auxiliary chassis may be used to convert the unit to 460 volt operation. This chassis is factory-wired for a 460 V input and an output of 230 volts. In wiring the chassis, adapt main unit for 230 volt operation (refer to para 2-16). Test chassis input rotation (para 2-24); then check chassis-to-unit rotation.

2-18. 415 VOLT OPERATION. Use the optional auxiliary chassis to convert the unit to 415 volt operation. This chassis is factory-wired for 460 volt operation and, therefore, requires a minor wiring alteration to accept the 415 volt input. Simply relocate the yellow wire at tap 4 of each transformer primary to tap 3. Then follow procedure outlined under para 2-16 to adapt the main unit for 230 volt input from the chassis. See Figure 2-2 for auxiliary chassis tapping arrangement. Test chassis input phase rotation (para 2-24); then check chassis-to-unit rotation.

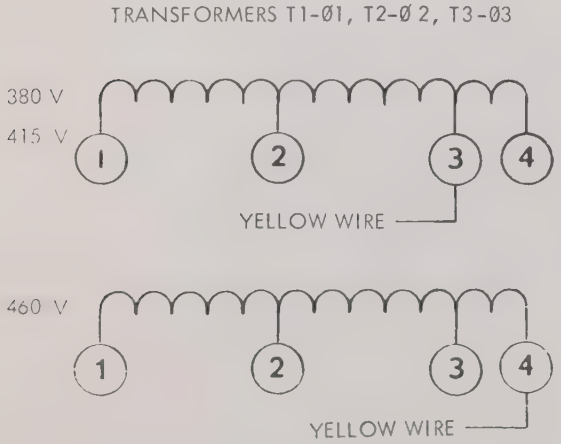


Figure 2-2. Auxiliary Chassis Input Connections.

2-19. 380 VOLT OPERATION. To adapt unit for 380 volt operation (see Figure 2-2), remove yellow wire from tap 4 of each auxiliary-chassis transformer primary and reconnect at tap 3. Test chassis input phase rotation (para 2-24); then check chassis-to-unit rotation.

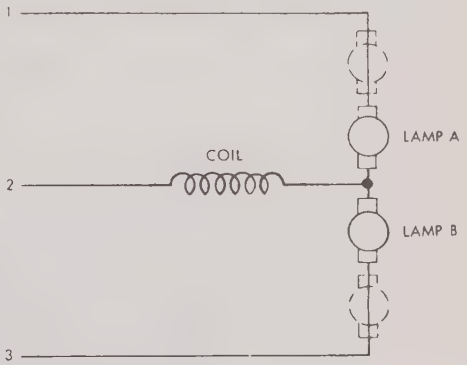
2-20. INITIAL CHECKOUT.

2-21. VOLTAGE MODE. To perform a check of voltage-mode regulation, proceed as follows:

a. Assure that proper input connections have been made. Refer to para 2-14 through 2-19.
b. Turn COARSE and FINE VOLTAGE ADJUST and CUR. ADJ. AMPS controls fully counterclockwise.

NOTE

See Figure 3-1 for location of controls and indicators.



INPUT	LAMP A	LAMP B	COIL
208 V, 230 V	230 V, 100 W	230 V, 100 W	1 Henry *
380 V, 415 V, 460 V	Two 230 V, 100 W	Two 230 V, 100 W	2 Henry *

* A 10 µF capacitor may be used in lieu of a 1 henry coil for 208 V or 230 V input. With a 380 V, 415 V or 460 V input, a 5 µF capacitor may be used as a substitute for the 2 henry coil.

Figure 2-3. Phase Rotation Test Set-up.

c. Set unit circuit breaker to ON.
d. Turn COARSE VOLTAGE ADJUST control slowly clockwise and observe unit voltmeter. Pointer should swing up scale.
e. With 20 volts indicated on the meter, turn FINE VOLTAGE ADJUST control from stop-to-stop. Range should be about 2 volts.
f. Set circuit breaker to OFF position.

2-22. CURRENT MODE. To check operation of unit in the current mode, proceed as follows:

a. Turn FINE and COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS controls fully counterclockwise.

2-22. (Cont.)

b. Connect a 0-1 volt dc voltmeter across the unit output terminals.

c. Make certain properly sequenced three-phase input is available, and then set unit circuit breaker to ON.

d. Rotate FINE VOLTAGE ADJUST control until 0.1 volts is indicated on test voltmeter.

e. Open circuit breaker, and disconnect test voltmeter. Connect about a two-foot length of No. 8 wire across output terminals.

f. Close unit circuit breaker. CURRENT MODE indicator will glow.

g. In steps using small increments, rotate CUR. ADJ. AMPS to 50 A while observing ammeter. Ammeter should indicate output equal to that set on control

h. Set unit circuit breaker to OFF.

i. Remove shorting wire from output terminals.

2-23. PHASE-ROTATION CHECK.

2-24. The DCR is a phase-rotation sensitive unit, with a rotation sequence of 1-2, 2-3, 3-1. To check rotation:

a. Connect two lamps and a coil as shown in Figure 2-3 for 208 or 230 volt inputs. Mark the free-ended leads 1, 2 and 3 as indicated in the figure.

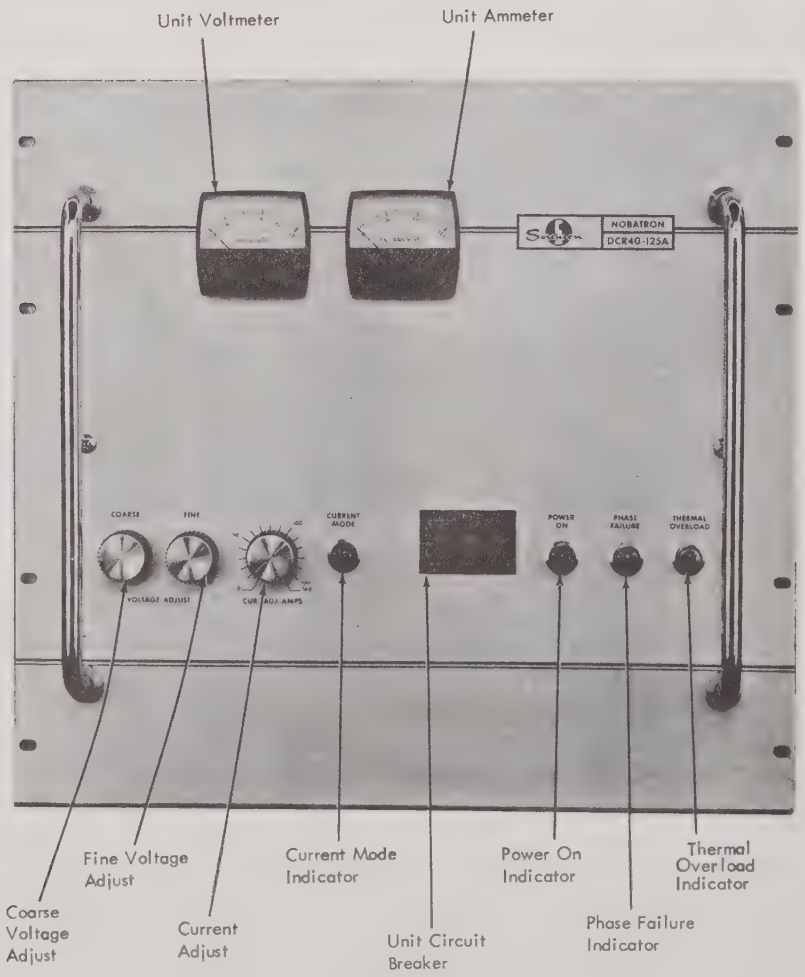
b. Hook-up the 3 phase input leads to the test circuit and apply power.

c. Observe the lamps. If lamp A is brighter than lamp B, the phase sequence is correct. If, however, lamp B is brighter than lamp A, disconnect input power and interchange input connections at 2 and 3. If a capacitor is used in test circuit, sequence is correct if lamp B is brighter than A.

d. Apply power and observe lamps. Lamp A should be brighter than B.

e. Tag mark the input leads 1, 2 and 3 to correspond with markers on test apparatus leads.

f. Disconnect power and then disconnect input leads from test set-up. Connect input leads to unit or auxiliary supply at proper terminals, i.e. input lead 1 to terminal 1, etc.



SECTION III
CONTROLS AND INDICATORS

This section provides a tabular listing of the unit's controls and indicators, along with a brief description of their function. The physical location of the controls and indicators is shown in Figure 3-1; for schematic locations, see Figure 5-3 following Section VII.

CONTROL/INDICATOR	FUNCTION
COARSE VOLTAGE ADJUST	A 3 kOhm potentiometer across which the reference voltage for voltage-mode operation is developed. Used to adjust the output voltage from 0 to 20 volts.
FINE VOLTAGE ADJUST	A 150 ohm potentiometer connected in series with the COARSE VOLTAGE ADJUST potentiometer and used to make small but sensitive variations in the output voltage.
CUR. ADJ. AMPS	A 150 ohm potentiometer used in the first stage of the current mode amplifier to vary the reference and subsequently the output current from 0 to 250 amperes.
CURRENT MODE Indicator	A green light which, when glowing brightly, indicates that the unit is operating in the current regulating mode.
Unit Circuit Breaker	A 250 V, 40 A, three-pole circuit breaker wired between the input terminal board and the main transformer. Used to connect, or disconnect, incoming power to, or from, the unit, and to protect the unit in event of internal failure.
POWER ON Indicator	A red light, connected across the secondary of transformer (T5), which, when glowing, indicates that the unit circuit breaker is closed and that at least one phase of input power is being supplied to the main transformer.
PHASE FAILURE Indicator	An amber light which, when glowing, indicates a failure of a phase of input power. This type of failure will drop output automatically to zero.
THERMAL OVERLOAD Indicator	An amber light which, when glowing, indicates unit is overheating. A thermal failure causes an automatic drop to zero output.
Unit Ammeter	A 0 to 300 A ammeter connected in the positive leg of the unit output. Indicates output current.
Unit Voltmeter	A 0 to 25 V voltmeter connected internally across the SENSE terminals of terminal board (TB2) to give an indication of unit voltage output.

TABLE 3-1. Controls and Indicators.

← Figure 3-1. Typical Controls and Indicators (Model DCR40-125A shown)

SECTION IV
OPERATING INSTRUCTIONS

4-1. GENERAL.

4-2. This section provides instructions on how to adapt the unit to many of its varied applications. It delineates procedures to be followed for conversion to remote-sensing operation, voltage-, current- and resistance programming modes, and series and parallel operation.

4-3. LOCAL SENSING.

4-4. The unit is shipped ready for use in the local-sensing mode. This simply means that the sensing circuit is connected across the unit output terminals, and therefore, the unit is voltage regulating at these terminals and not at the load. For applications where the voltage drop in the load lines is prohibitive, use remote sensing (para 4-7). Figure 4-1 illustrates the local-sensing configuration of terminal board (TB2).

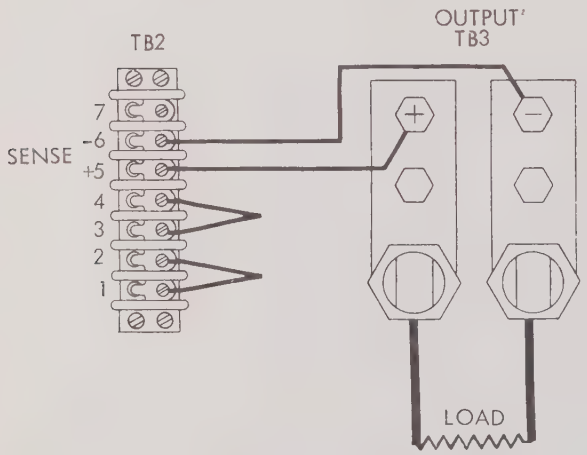


Figure 4-1. Local-sensing Configuration.

4-5. VOLTAGE MODE. To put the unit in voltage-mode operation, proceed as follows:

a. Rotate the FINE and COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS potentiometers (see Figure 3-1) fully counterclockwise.
b. Connect the three-phase input leads as stipulated under para 2-13.
c. Set unit circuit breaker to ON. POWER ON light glows.
d. Rotate COARSE VOLTAGE ADJUST until the unit voltmeter indicates the desired output voltage. Use FINE VOLTAGE ADJUST for small sensitive adjustments.

NOTE

For output below 1 V, connect a 0.5 ohm bleeder across output terminals to preclude inherent SCR random firing at extremely low output.

e. Set unit circuit breaker to OFF.
f. Connect load lines to unit output terminals on terminal board (TB3).
g. Turn CUR. ADJ. AMPS control to the desired current-limiting value (0-250A)

NOTE

Regulation falls off if output current is within 10% of limiting value. See Figure 1-1. Current Mode indicator begins to glow when current output is within approximately 15% of limiting value.

h. Set unit circuit breaker to ON. POWER ON light glows, and the unit is in voltage-mode operation.

NOTE

With unit in the voltage mode, an increase in load current requirements above value set in step "g" will cause an automatic crossover to current-mode (current-limiting) operation.

4-6. CURRENT MODE. To operate unit in the current mode, proceed as follows:

a. Rotate the FINE and COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS controls (see Figure 3-1) fully counterclockwise.
b. Connect three-phase input (para 2-13).
c. Set unit circuit breaker to ON.
d. Rotate COARSE VOLTAGE ADJUST until unit voltmeter indicates 1 volt above the desired dynamic voltage.

NOTE

Current regulation falls off if the dynamic (compliance) voltage is within 5% of voltage limiting value. (See Figure 1-1.)

e. Set unit circuit breaker to OFF.
f. Connect load lines to unit output terminals on terminal board (TB3).
g. Turn CUR. ADJ. AMPS control to desired current-regulating value. POWER ON light glows, and unit is in current-mode operation.

NOTE

If compliance (dynamic) voltage rises above limit set in step "d", the unit automatically crosses over to voltage-mode operation.

4-7. REMOTE SENSING.

4-8. A few link changes at the rear panel and alterations at the load terminations of the output leads are all that are required to convert the unit to remote-sensing operation. In this mode, voltage regulation is at the load rather than at the unit output terminals, thus correcting for voltage drops in the load lines.

NOTE

A 3 volt drop per line is the maximum for which remote sensing will compensate. Voltage across load is equal to voltage output of unit minus line drops.

4-9. To adapt unit for remote-sensing operation, proceed as follows:

a. Set unit circuit breaker to OFF.
b. Remove local-sensing leads at the plus and minus SENSE of board (TB2)

WARNING

When the unit is returned to operation, the loose ends of the local-sensing leads will be HOT. To preclude the possibility of injury to personnel, tape lead ends individually and fold back from both the output terminal board (TB3) and the control terminal board (TB2)

c. Tightly secure remote-sensing leads to + and - SENSE terminals. Note which lead is connected to the + terminal (remote-sensing configuration is represented diagrammatically in Figure 4-2).

NOTE

Use a twisted or shielded pair of wires for the sensing leads. Sensing current is about 10 mA.

d. Connect the lead from the positive sense terminal to the positive load terminal; connect the other lead at the negative load terminal.
e. Reset current limit per para 6-14.
f. If the unit is being placed in line for the first time or is being returned to the line following a maintenance check, etc., proceed as outlined under para 4-5. Otherwise, set unit circuit breaker to ON. POWER ON indicator glows and the unit supplies load.

4-10. EXTERNAL RESISTANCE PROGRAMMING.

4-11. VOLTAGE MODE. The unit output voltage may be programmed externally to a predetermined, regulated value. This is done by connecting a resistance into the voltage reference circuit of the voltage-mode section. Terminals on TB2 are provided for this purpose

4-12. Voltage-programming sensitivity is approximately 160 ohms per volt, plus or minus 10 percent. This means that for a certain voltage output, the voltage value must be multiplied by 160 to obtain the programming resistance. The resistor used should have a low temperature coefficient (± 30 ppm) to maintain the unit's rated temperature characteristics as well as stability. Programming current is about 2 ma. Choose a resistor with a wattage rating at least 10 times that calculated. For a precision calibration of the ohms per volt, see para 4-14.

4-13. To adapt unit to external voltage programming, proceed as follows:

a. Set unit circuit breaker to OFF .
b. Remove link between terminals 3 and 4 (VOLT PROG) on terminal board (TB2) and retain.
c. Connect programming resistor across terminals 3 and 4 (see Figure 4-3 for a diagram representation of voltage programming hook-up).
d. Rotate COARSE and FINE VOLTAGE ADJUST potentiometers fully counterclockwise.

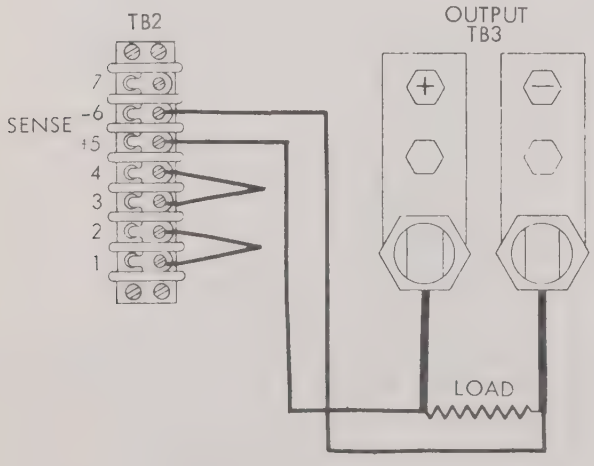


Figure 4-2. Remote-sensing Configuration.

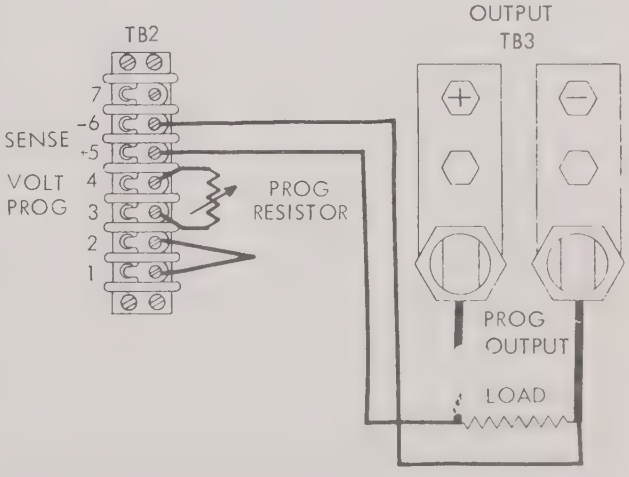


Figure 4-3. Voltage Resistance Programming (with remote sensing)

4-13 (Cont.)

NOTE

The voltage adjust potentiometers are in series with the programming device. Rotation of either of these controls from zero position will affect programmed voltage.

e. If the unit is being used for the first time or is being returned to the line following a maintenance check, etc.,assure that input is connected properly (para 2-13) and that a current-limiting value is set on CUR. ADJ. AMPS control.

NOTE

Regulation will drop off if output current is within 10% of set limit.

f. Set the unit circuit breaker to ON. POWER ON indicator glows

CAUTION

If voltage programming is to be discontinued, remove programming device and REINSERT LINK BETWEEN TERMINALS 3 and 4 of terminal board (TB2).

4-14. PRECISION CALIBRATION (Voltage Mode). If it is desired to calibrate precisely the programming ohms per volt, proceed as follows:

a. Rotate COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise.
b. Remove link between terminals 3 and 4 (VOLT PROG) on terminal board (TB2) and retain.
c. Connect a precision 3.2 kohm resistor between terminals 3 and 4.
d. Set unit circuit breaker to ON. Allow at least a 30 minute warm-up period.
e. Connect a precision voltmeter across output terminals. Set voltmeter for a range of at least 30 volts.
f. Adjust resistor R39 on component board assembly (located at rear of unit behind left-hand panel) for output reading of approximately 20 volts.
g. Short circuit precision resistor.
h. Adjust resistor R43 on component board assembly for a 0 ± .1 volt output (reset voltmeter range).
i. Remove short circuit, reset voltmeter range to at least 30 volts and adjust R39 for an output of 20 ± .3 volts.
j. Disconnect precision voltmeter.

NOTE

Unit is now calibrated to programmed voltage ± (.3% + tolerances of precision resistor and voltmeter, and regulation of unit). Linearity of programming is ± .5%.

k. Remove precision calibrating resistor and insert programming resistor. Refer to para 4-12.

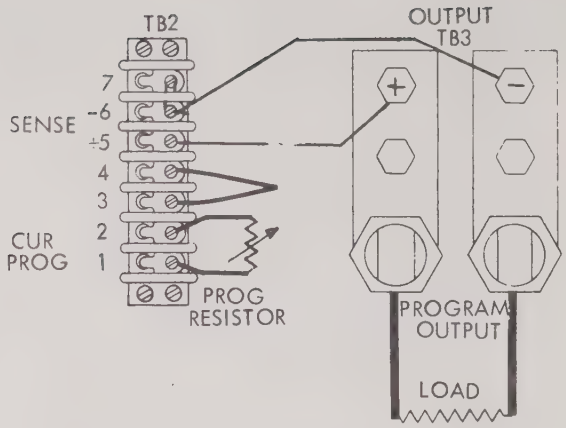


Figure 4-4. Current Resistance Programming.

4-15. CURRENT. The unit may be programmed externally to provide a fixed, predetermined output current. This is accomplished by inserting a resistor in the current-mode section reference-voltage circuit (see Figure 4-4 for a diagram illustrating the current-programming configuration).

4-16. Current-programming sensitivity is 0.6 ohms per ampere. In other words, for every ampere of desired output, the programming resistance must be increased by 0.6 ohms. Programming voltage is about 0.6 V. Use a resistor with a low temperature coefficient (30 ± ppm) and a wattage rating at least 10 times calculated value.

4-17. To convert the unit to current-programming mode, proceed as follows:

a. Set unit circuit breaker to OFF.
b. Remove link between terminals 1 and 2 (CUR PROG) of terminal board (TB2).
c. Insert programming resistor across terminals 1 and 2.
d. Rotate CUR. ADJ. AMPS and COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise.
e. If the unit is being used for the first time or if it is being returned to operation following a maintenance check, etc., assure that a 3-phase input is properly connected (para 2-13).
f. If applicable, disconnect load lines; then, set unit circuit breaker to ON.
g. Rotate COARSE VOLTAGE ADJUST control until unit voltmeter indicates one volt above desired dynamic voltage.

NOTE

Current regulation will drop off if dynamic voltage rises to within 5% of voltage setting.

h. Set unit circuit breaker to OFF, and reconnect load lines.

i. Set unit circuit breaker to ON. POWER ON indicator glows.

CAUTION

If current programming is to be discontinued, remove programming device and REINSERT LINK BETWEEN TERMINALS 1 and 2 of terminal board (TB2)

4-18. EXTERNAL SIGNAL PROGRAMMING.

4-19. VOLTAGE. The unit may be programmed externally to provide a variable output as a function of an input voltage signal. This is done by introducing the external signal into the voltage-reference circuit of the voltage-mode stage.

4-20. In selecting a signal source, the following should be considered:

(1) The source must be capable of absorbing about 2 mA (the programming current).

(2) A floating (ungrounded) source must be used.

(3) To obtain a full 0 to 20 volt output range the source must provide a 0 to 8 volt signal (approximately).

4-21. To convert the unit to external voltage signal programming, follow procedures outlined under para 4-13,with one exception. Where step "c" calls for insertion of a resistor across terminals 3 and 4, connect the signal source instead (see Figure 4-5 for connection representation).

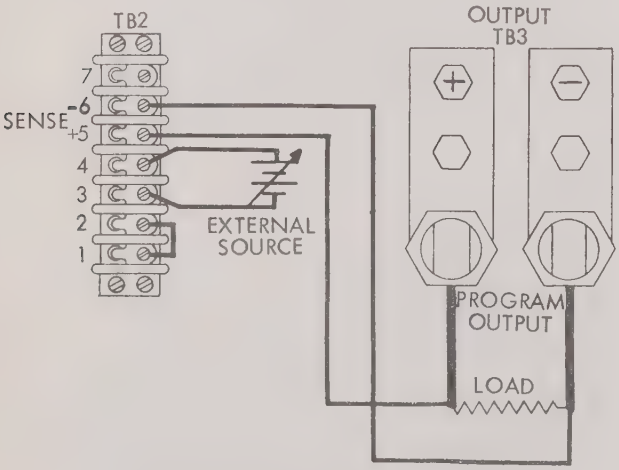


Figure 4-5 Voltage Signal Programming(with remote sensing)

4-22. CURRENT. A current may be introduced into the reference circuit of the current-mode section to provide a variable current output. This output will be a function of the input signal.

4-23. In choosing a signal source, the following should be considered:

(1) The source must be capable of absorbing about 3 mA,

(2) it must be ungrounded and,

(3) for full rated output range (0 - 250 A) it must provide a 0 to 0.6 volt signal (approx.)

4-24. To adapt the unit to external current-signal programming, follow procedures in para 4-17, with this exception: instead of inserting a programming resistor across terminals 1 and 2 as stated in step "c", insert the programming source. For diagrammatic representation of connections, see Figure 4-6.

4-25. ALTERNATE PROGRAMMING METHODS.

4-26. There is an alternate programming method, for each mode, which eliminates the possibility of altering the programmed output by varying the applicable front-panel control. This is not a preferred method for two reasons: (1) flexibility in using local and external programming together is eliminated and (2) for the voltage mode, the unit voltmeter reads in reverse.

4-27. VOLTAGE RESISTANCE. To use alternate programming method, read and follow the procedures outlined in para 4-11, 4-12, and 4-13, with one exception. Instead of connecting program resistor between terminals 3 and 4 (VOLT PROG) of terminal board (TB2) as stated in step "c" of para 4-13, connect resistor between terminal 3 and terminal A (terminal A is located on the upper right-hand side of the component board immediately adjacent to TB2).

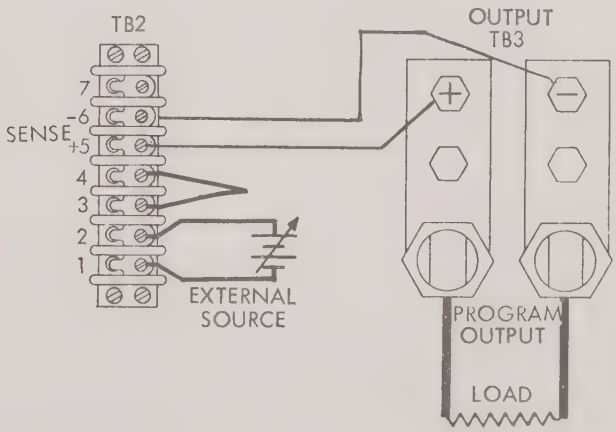


Figure 4-6. Current Signal Programming.

4-28. CURRENT RESISTANCE. To adapt unit for current programming, using alternate method, proceed as outlined in para 4-15, 4-16, and 4-17 with this exception. Insert programming resistor between terminal F and terminal D (located on the component board immediately adjacent to TB2). This step replaces step "c" of para 4-17.

4-29. VOLTAGE SIGNAL. To use alternate programming method, read and follow procedures outlined in para 4-19, 4-20 and 4-21, with one exception: instead of connecting signal source across terminals 3 and 4 (VOLT PROG) connect the source across terminal 3 and terminal A (located at upper right-hand side of component board assembly immediately adjacent to terminal board TB2).

4-30. CURRENT SIGNAL. To use alternate programming method, read and follow procedures outlined in para 4-22, 4-23 and 4-24, with one exception instead of connecting signal source across terminals 1 and 2 (CUR PROG) connect source between terminal F and terminal D (located on component board assembly, immediately adjacent to terminal board TB2).

4-31. PARALLEL OPERATION.

4-32. Paralleling of three-phase DCR units is accomplished directly by connecting individual supplies to the load. Using this method, no current derating due to composite tolerances of wire resistance, components, etc. is required. There are no restrictions on the number of units that may be paralleled. However, paralleling units does result in lower overall regulation.

4-33. The following delineates procedures to be followed in directly paralleling two units. However, the procedures are applicable to any number of units (see representative diagram in Figure 4-7).

NOTE

The paralleled units may be adapted for remote-sensing as illustrated in Figure 4-7. They may also be adapted for resistance or signal programming. However, none of these is required for parallel operation.

a. Set unit circuit breakers of both units to OFF.

b. If applicable, disconnect output lines and sensing leads at both units.

c. Set both unit circuit breakers to ON. POWER ON indicators glow.

d. Rotate COARSE VOLTAGE ADJUST control at one unit to desired output; repeat procedure for other unit. Match unit output voltage by using respective FINE VOLTAGE ADJUST controls.

e. Set CUR. ADJ. AMPS control on each unit to one-half of the total desired limiting current, e.g., if desired to limit load current at 150 A, set each control to 75 A.

f. Connect output cables from each unit to load. If desired, connect the remote-sensing leads of each unit to load.

g. Set both unit circuit breakers to ON. POWER ON indicators glow. The unit which is supplying the highest voltage (it is impossible to identically match the output voltages) will supply load. If the load requirements exceed the setting on CUR. ADJ. AMPS control, this unit will automatically crossover to current-mode operation and its output voltage will drop. The second unit will then assume that portion of the load rejected by the first. Any further increases in load will be supplied by the second unit up to its current-limiting setting. Regulation, therefore, will be the sum of the regulation of the two units plus the difference in the voltage settings.

4-34. SERIES OPERATION.

4-35. Series operation allows the user to connect as many as five 20 volt DCR units in series to provide a total output of 100 volts. No derating is inherent in series operation. Regulation is the sum of the regulations of all units.

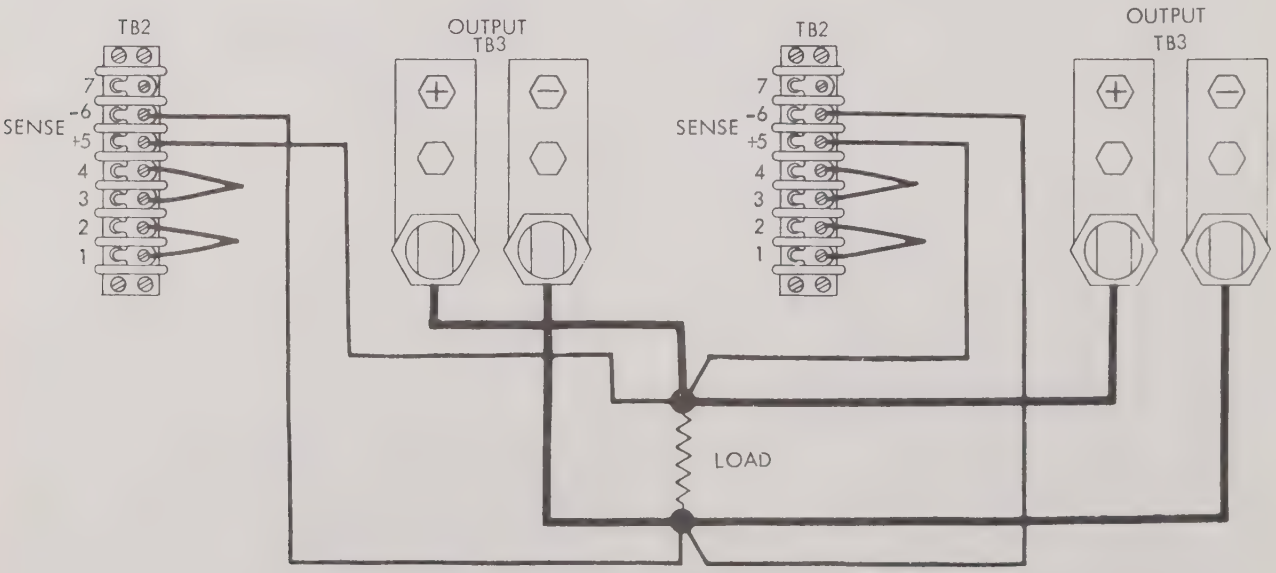


Figure 4-7. Parallel Operation (with remote sensing).

4-36. The following outlines procedures for connecting two units in series. Identical procedures may be employed for series connecting up to five units. (See Figure 4-8 for a diagrammatic representation of series interconnections.)

NOTE

Series units may be connected for remote sensing as indicated in Figure 4-8 or they may be adapted to resistance or signal programming. However, none of these is required for series operation.

a. Set desired voltage output of each unit at no load using COARSE and FINE VOLTAGE ADJUST Select current-limiting value.

b. Set unit circuit breaker on both units to OFF.

c. Connect an output lead from the positive output terminal of one unit (for the sake of clarity, call this unit 1) to the negative output terminal of unit 2.

d. Connect an output lead from the unit 1 negative terminal to the load; connect the other output lead from the unit 2 positive terminal to the load

CAUTION

In series operation, rectifiers must be connected across each set of output terminals as shown in Figure 4-8. Failure to do so may result in damage to output capacitors. See para 4-37 for information on rectifier selection.

e. If remote sensing is desired, proceed as follows:

(1) Connect a sensing lead from terminal 6 (-SENSE) on unit 1 terminal board (TB2) to the load termination of unit 1 negative output lead. If applicable, remove local-sensing lead (black wire at terminal 6) tape loose end and fold back.

(2) Connect a sensing lead from terminal 5 (+SENSE) on unit 1 terminal board (TB2) to the negative output terminal of unit 2 terminal board (TB3) If applicable, remove local-sensing lead at terminal 5 of unit 1 terminal board (TB2) tape loose end and fold back. Do not remove local sensing lead at terminal 6 of unit 2 terminal board (TB2). If necessary, reconnect.

(3) Run a sensing lead from terminal 5 (+ SENSE) of unit 2 terminal board (TB2) to the load termination of the unit 2 positive output cable. If applicable, remove local sensing lead at terminal 5, tape loose end and fold back.

f. Set unit circuit breakers to ON. POWER ON indicators glow. Each unit operates as a separate entity with the output of each independently adjustable. Each may be turned on or off separately.

4-37. SERIES OPERATION RECTIFIER. When operating units in series, connect rectifiers across the individual unit outputs. Table 4-1 provides a listing of rectifiers recommended for this purpose. The rectifier and heat sink combination under column A is less expensive than that under column B. However, the rectifiers in column B are JEDEC types and may be obtained from more than one source.

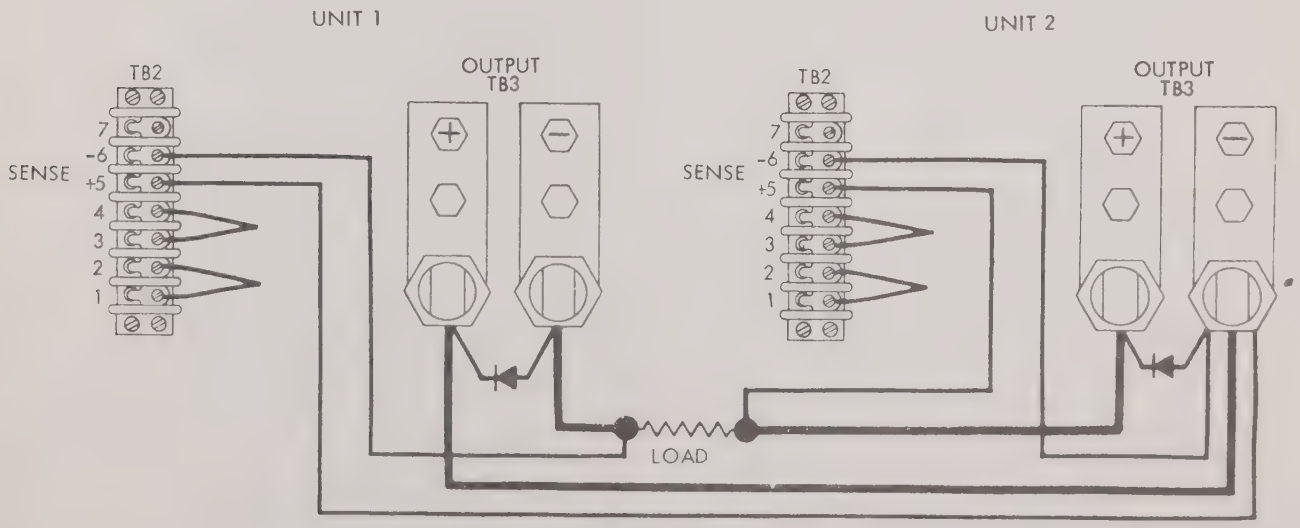


Figure 4-8. Series Operation (with remote sensing).

4-37 (Cont.)

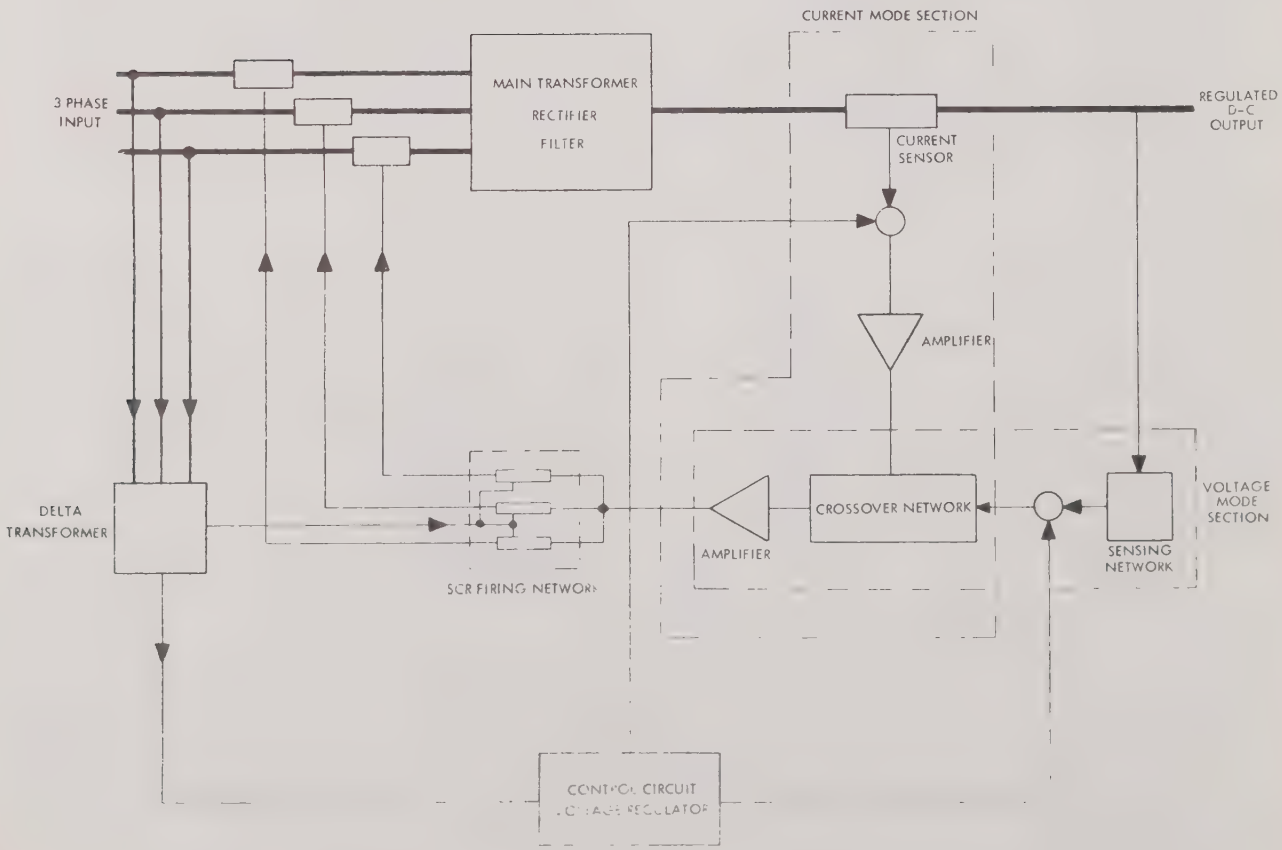
The heat sinks have been recommended on the assumption that the user will mount one forward and one reverse polarity rectifier on each. If this is not the case, a separate heat sink must be used for each rectifier.

Rectifier	A	B
Manufacturer	Motorola	
Part No.*	MR 1220SB MR 1220SBR MR 1220SL MR 1220SLR	1N4044 1N4044 R
Stud	3/4 in.	3/4 in.
Hex.	1-3/4 in.	1-1/4 in.
Mounting Torque (dry)	25-33 lb-ft	25-30 lb-ft **
Heat Sink		
Manufacturer	Wakefield	Wakefield
Part No.	WN 1541-6-22	WN 1541-9WW

* An "R" suffix after rectifier part numbers indicates reverse polarity. "SB" following Motorola part numbers means flexible lead and "SL" indicates lug type.

** With dished nut, correct torque may be obtained by rotating 1/2 turn beyond finger tight.

Table 4-1. Series Operation Rectifier Recommendations.



SECTION V
PRINCIPLES OF OPERATION

5-1. INTRODUCTION.

5-2. This section is designed to provide the user with a general knowledge of the internal operation of his unit. An understanding in this area is essential to the rapid and logical isolation of any unit malfunction.

5-3. To facilitate the treatment of what is a relatively complex subject, a brief sketch, with reference to unit block diagram in Figure 5-1, is given first. This is followed by detailed discussions on the various section and sub-sections which comprise the block diagram.

5-4. FUNCTIONAL DESCRIPTION.

5-5. For an understanding of basic unit operation, it is important to understand what is meant by phase control. Consider Figure 5-2, which, for the sake of simplicity, represents only a single-phase input voltage to a resistive load. If by some means, conduction of this voltage can be delayed, then the average voltage output of the positive half-cycle will be reduced. Control of the delay, then, results in control of the average voltage. This is phase control, and the device used in the model DCR to effect this delay is the silicon controlled rectifier (SCR). The delay is expressed in degrees and is known as the firing angle. Figure 5-2 shows firing angles of 60° (shaded area plus cross-hatched area) and 120° (cross-hatched area only).

5-6. A discussion of the block diagram in Figure 5-1 follows: in the main power circuit, the three-phase input voltage is fed into the main transformer and SCR control. The output of the transformer is rectified and then L-C filtered to deliver dc at the output.

5-7. In addition to the main transformer, there is an auxiliary transformer, delta connected across the input, which provides power for both a control-circuit voltage-regulator and the SCR firing network. This network uses transformer output to correctly sequence the SCR firings with the appropriate phase. The control-circuit voltage-regulator provides a highly stable, precise voltage for the voltage- and current-mode sections. The former section monitors the output voltage, and when variations occur in the output, it signals the SCR firing network to alter the SCR firing angle. This results in either a compensating increase or decrease in the main transformer output, which is reflected instantaneously in the unit output.

5-8. The current-mode section performs basically the same function as the voltage-mode only it is, of course, monitoring current output while the unit is current regulating.

5-9. DETAIL DESCRIPTION.

5-10. The following paragraphs provide a detailed functional description of the various operating sections. For schematic location of the parenthetic reference designations used liberally throughout the discussions, see Figure 5-3 following Section VII.

5-11. CONTROL CIRCUIT VOLTAGE REGULATOR.

5-12. The control-circuit voltage-regulator provides 20 volts of highly stable, precise output. It consists of two differential amplifiers (Q5, Q6 and Q3, Q4), a zener diode (CR20), a passing stage (Q2) and a constant-current generator (CR18, CR19, R14, R15 and Q1). Output appears across capacitor (C10). This section is supplied by transformer (T4) through a center-tapped, full wave bridge (CR16, CR17).

5-13. The output voltage of the supply is sensed across potentiometer (R20), where a portion of the drop here is compared with a voltage reference created by diode (CR20). Resulting error signals are amplified and fed to the base of passing stage (Q2). Q2 acts as a variable impedance, increasing or decreasing the voltage drop across the stage as a function of the output voltage.

5-14. As an example of circuit operation, assume that a rise in voltage is sensed across R20. The base of Q6 will become more positive, and more current will flow through the transistor. This results in a decrease in the current available for the base of Q4. Q4 conducts less, and transistor Q3 conducts more. Since the current from generator (Q1, CR18, CR19, R14, R15) is constant, an increase in current through Q3 results in a decrease in current to the base of passing stage Q2. This effectively increases the impedance and the voltage drop across the stage. The rising voltage is then curtailed by the drop to ensure that a 20-volt potential is maintained.

5-15. VOLTAGE MODE SECTION.

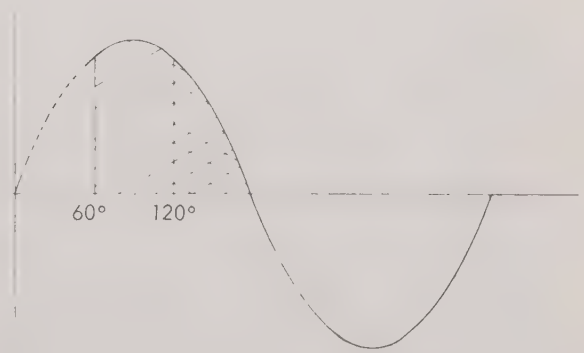


Figure 5-2. Single-Phase Input Wave.

Figure 5-1. Unit Block Diagram.

5-16. The voltage-mode section monitors the output voltage, detects variations and fluctuations and sends an error signal to the SCR firing network. It consists of a differential amplifier (Q12, Q13), constant-current generators (Q9, Q11, Q14 and their associated circuitry) and emitter follower (Q7).

5-17. The circuit functions as follows: output voltage is divided across resistors (R51, R52), a beta network, with a sample of the voltage appearing across the base-emitter of transistor (Q13). This voltage is compared with a reference voltage developed across resistors (R41, R42, R43). The resulting voltage error will cause an increase in current in either Q12 or Q13. An increase in Q12 current will occur if the sensed output voltage is decreasing; Q13 current will increase if output voltage is increasing. For example, if the output voltage starts to rise, the base of Q13 will become more positive resulting in an increase of current through Q13. Inasmuch as current generator (Q14) will only pull a constant current and since the current through Q13 has increased, the current through Q12 and, therefore, resistor (R46) will decrease. The voltage drop across the resistor will decrease, and this drop will be reflected in the output of emitter follower (Q7). Q 7 output is directed to the SCR firing network where its voltage level is used as a determinant in firing-angle delay.

5-18. Constant-current generator (Q9) supplies an operating current to transistor (Q12), allowing resistor (R46) to have a large value. This large value results in greater gain.

5-19. The voltage reference for the differential amplifier, derived from both the constant voltage of the internal voltage regulator (refer to para 5-11) and a constant current generated by Q11, is developed across resistors (R41, R42 and R43). R41 and R42 are the control-panel potentiometers which, by varying the amplifier reference voltage, adjust the output voltage. No variations in differential-amplifier current due to the variable reference voltage are observed because transistor (Q14) pulls a constant current through the amplifier.

5-20. CURRENT-MODE SECTION.

5-21. The current-mode section consists primarily of current-sensing resistor (R13), variable resistors (R23, R24, R25), amplifier (Q8, Q10) and diode (CR23). These function in conjunction with constant-current generator (Q14) to effect crossover and limit the current output to the selected value.

5-22. The circuit works as follows: when the output current rises above the selected value (R24 is the current output adjust), the drop occurring across resistor (R13) is sufficient to reduce the conduction level of Q8. The collector output of Q8 is then fed to the base of Q10, which increases the current flow through this transistor. Its output is fed both to the emitter of Q14 and the base of Q15. Sufficient drive on the base of Q15 will result in the energization of the current-mode indicator circuit. The current into the emitter of Q14, however, provides the limiting feature. This current may be considered as part of the constant current of Q14. Therefore, the current into the collector of Q14 must decrease to maintain the constant level. This results in a drop in the voltage across resistor (R46). This diminution is reflected in the output of emitter follower (Q7) and subsequently results in an increased delay of SCR firing. This reduces the output current.

5-23. Reference for amplifier (Q8) is provided by the voltage-regulator section (refer to para 5-11) and resistors (R23, R24, R25, and R26).

5-24. SCR FIRING NETWORK.

5-25. Three separate but identical firing circuits, one for each phase, comprise the firing network. Power for the network is derived from transformer (T4). This transformer has a delta-connected primary, and three single-phase and two wye-connected secondaries. The single-phase secondaries are connected to the firing circuits, one per phase. This insures the correct phase relationship between a firing circuit and the voltage across its SCR. A typical firing circuit consists of resistor (R59), zener diode (CR28) transistor (Q16), capacitor (C21), unijunction transistor (Q17) and pulse transformer (T6). On Figure 5-3, the remaining two circuits are located directly below the aforementioned.

5-26. Basically, the circuit works as follows: input from the secondary of transformer (T4) is clipped by zener (CR28), and fed across transistor (Q16) and unijunction transistor (Q17). Q16 is a constant-current generator whose output is determined by the voltage drop across R22 in the emitter-follower (Q7) circuit. (The drop across R22 is a function of the main output. Refer to para 5-17 and 5-22). Q16, then, controls the charge rate of capacitor (C21). This rate is important since the charge on C21 determines the firing point of unijunction transistor (Q17). As the charge builds up, Q17's breakover voltage is surpassed and C21 discharges through Q17 to the pulse transformer (T6). The pulse is fed to the gate of silicon-controlled rectifier (CR1), and the SCR fires.

5-27. As a further amplification of circuit function, assume that there is a rise in output voltage. The drop across R22 is then lowered, and the current through Q16 is diminished. The charging rate of C1 is slowed, and discharge through Q17 is delayed. This results in a retardation in the SCR firing angle and a subsequent decrease in the average output of bridge (CR11, CR12).

5-28. PHASE-FAILURE SHUTDOWN.

5-29. If a phase of input line fails, a lamp (DS4) will glow and unit output will go to zero. The failure sensing and shutdown circuit consists of two wye-connected secondaries of transformer (T4), diodes (CR31 through CR36), relays (K1, K2) , lamp (DS4), resistor (R71), and constant-current generator (Q14).

5-30. The circuit functions as follows: removal of an input phase will cause an unbalance in the phase voltages being compared across relays K1 and K2. This unbalance causes a current to flow in either relay, and the affected relay trips. Closing of either relay's contacts makes the

circuit between a power source (CR34, CR35, CR36) and the indicating light. The current flowing through the light is also introduced into the emitter circuit of Q14, and causes a large decrease in the current flowing through R46. The output then drops to zero (refer to para 5-17 and 5-26 for an explanation of how a drop in the voltage across R46 decreases the main output voltage). Resistor (R71) across lamp (DS4) insures shut down if the lamp burns out.

5-31. THERMAL OVERLOAD SHUTDOWN.

5-32. If the unit overheats, one of three thermostats (eitner S1, S2 or S3) energizes lamp (DS1) to give an indication of failure and also introduces a large current into the emitter of Q14. The output voltage then drops to zero due to the decrease in drop across resistor (R46). (Refer to para 5-17 and 5-26 for an explanation of how this comes about.) Resistor (R55) insures operation of the fan-failure circuit in the event of lamp (DS1) failure.

5-33. RADIO FREQUENCY SUPPRESSION.

5-34. Choke coils (L1, L2 and L3) and capacitors (C37 through C40) suppress radio-frequency interference arising from semiconductor commutation.

SECTION VI
MAINTENANCE

6-1. GENERAL.

6-2. This section is designed to provide the user with sufficient data for the maintenance and repair of his unit. In addition, calibration procedures are included which, if performed as specified, will serve to keep the unit at peak performance throughout its long operating life.

6-3. The material herein is presented as follows: a general troubleshooting chart outlines obvious troubles for common symptoms. Where these common troubles require deeper analysis, a reference is made to a test procedure. The results of this dynamic test procedure will provide an evaluation of a particular section's performance. If a section's performance is not as specified, then a further reference is made to a local troubleshooting chart, where a listing of possible component failures is provided. Calibration procedures are described next, followed by performance testing. The section terminates with periodic servicing.

NOTE

It is recommended that only personnel with experience in the maintenance of equipment using semiconductor devices be permitted to repair the DCR. It is further recommended that these personnel study Section V before attempting such repair.

6-4. TESTING.

6-5. The next few paragraphs outline the procedures for dynamic testing of the unit's major sections. The tests are ordered as follows: control-circuit voltage regulator, voltage mode section and current-mode section. It is recommended that, whenever testing is done, this order be maintained

NOTE

If components such as unijunction transistors (Q17, Q19 and Q21) or components from the differential amplifiers are replaced, recalibration may be required. Refer to para 6-9.

6-6. CONTROL-CIRCUIT VOLTAGE REGULATOR. To test the voltage-regulator section proceed as follows:

a. Remove unijunction transistor (Q17, Q19 and Q21). Power circuit is, in effect, disabled. Mark each transistor so that, when reinserting, transistor may be returned to socket from which removed.
b. Connect a 0-50 Vdc voltmeter across capacitor C10.
c. Apply nominal three-phase input to terminal board TB1 and close unit circuit breaker. Power is applied to voltage regulator through transformer. Voltmeter should indicate 20.0 ± 0.1 volts. If it does not, attempt to adjust using potentiometer R39. " Glyptal" R39 after adjustment.
d. Vary input voltage through entire range (refer to Tables 1-1 and 1-2, respectively, for unit and auxiliary supply input specifications). Regulation should be 2 mV or better.
e. If regulator does not perform as specified above, refer to Table 6-2 for troubleshooting. Terminate procedure by setting unit circuit breaker to OFF and reinserting transistors Q17, Q19 and Q21 in their respective sockets.

SYMPTOM	TROUBLE
No Output	a. Check input b. Unit circuit breaker tripped. (Check power circuit, diode CR23 and transistor Q15 if breaker continues to trip after repetitive resetting) c. Thermal overload circuit operative. THERMAL OVERLOAD indicator glows. Check for a defective thermostat. Check each cooling fan input voltage with a 120 V AC voltmeter. Voltage should be 120 ± 5 V AC d. Failure in control-circuit voltage regulator. Refer to para 6-6 e. Defect in voltage-mode section. Test section per para 6-7 f. Current-mode section failure. Refer to para 6-8
High Voltage Output	Failure in control circuit regulator. Refer to para 6-6 Failure in voltage-mode section. Refer to para 6-7
High Output Current (No limiting)	First test control circuit regulator and voltage mode section (para 6-6 and 6-7, respectively); then check current mode section per para 6-8
Low Output	a. Check input. See Table 1-1 and 1-2 for input specifications. b. Faulty control-circuit voltage regulator. Test per para 6-6 c. Failure in voltage-mode section. Refer to para 6-7 d. Defective current-mode section. Test per para 6-8 e. Silicon controlled rectifier open, or failure in firing network. See Figure 6-1 for oscilloscope patterns of both normal ripple at no load and ripple with a failed firing circuit
No Output	a. Input phase failed
PHASE FAILURE Light Glows	b. Open CR31, CR32 or CR33 c. Shorted CR16 or CR17

Table 6-1. General Troubleshooting.

SYMPTOM	TROUBLE
Regulator Output about 12 V	a. Transistors Q1, Q2, Q4 or Q5 open b. Transistor Q3 or Q6 shorted c. Potentiometer R20 defective (negative side open) d. Diode CR20 shorted e. Check input to regulator by connecting an oscilloscope (.5 V/cm, 1 msec/cm) and a 0-50 volt DC voltmeter across capacitor C9. Ripple should be about 1.2 V and voltage should be about 42 V.
Regulator Output about 30 V	a. Defective R20 (wiper open or positive side open) b. Transistor Q 3 open c. Diode CR20 open d. Shorted transistor Q2, Q4, or Q5. e. Diode CR18 or CR19 open

Table 6-2. Voltage Regulator Troubleshooting.

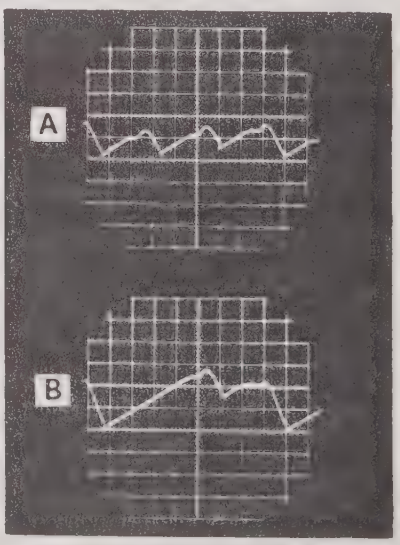


Figure 6-1. No-load Output Ripple.

(a) normal
(b) firing circuit failure (50mV /cm vertical; 2 msec /cm horizontal)

6-7. VOLTAGE-MODE SECTION. To test the voltage mode section, proceed as follows:

a. Remove unijunction transistors (Q17, Q19 and Q21). This effectively disables the power circuit. To insure that each transistor will be returned to socket from which it was removed, mark each for identification. Remove transistor (Q10).

NOTE

Shorting in power-circuit components may result in continued output. Check before proceeding.

b. Short the output terminals. The 20 volt regulator output will then appear across the beta network (R51 and R52).
c. Connect an oscilloscope across capacitor C21. Set vertical sweep to 5 V/cm; horizontal to 5 msec/cm.
d. Set COARSE and FINE VOLTAGE controls fully counterclockwise and CUR. ADJ. AMPS control to about 50 A.
e. Apply nominal input and close unit circuit breaker. The control-circuit voltage regulator will function on power supplied by transformer (T4).
f. Observe oscilloscope. A single horizontal line should be displayed. If a square wave pattern develops, it is indicative of high unit output voltage. Refer to Table 6-3.
g. Rotate FINE VOLTAGE ADJJST control a few degrees clockwise and observe oscilloscope. Repeat procedure until a sawtooth pattern appears on oscilloscope. The rise time of the sawtooth should be controllable by slight rotation of FINE VOLTAGE ADJUST.

NOTE

Lag time between rotation of control and unit response (as indicated on oscilloscope) is 5 to 10 seconds. A change of oscilloscope patterns from straight line to square-wave without a sawtooth is an indication that the increments of control rotation were too great. Repeat "g" using a smaller degree of turning.

h. The above procedures checked the voltage-mode section and a portion of the firing circuit (transistor Q16, diode CR28 and capacitor C21). Repeat entire procedure with the oscilloscope across capacitor C22 and then across capacitor C23. This will check a portion (Q18, CR29, C22 and Q20, CR30, C23) of each of the other two firing circuits.

NOTE

Inability to achieve a sawtooth across any of the capacitors is an indication of a voltage-mode section failure (refer to Table 6-3); lack of a sawtooth across a single capacitor is indicative of a failure in the firing circuit.

i. Terminate test by opening unit circuit breaker, removing short from output terminals and replacing transistors (Q17, Q19 and Q21) in their respective sockets. Reinsert transistor (Q10).

SYMPTOM	TROUBLE
No Unit Output. Straight line display on oscilloscope (refer to para 6-7)	a. Transistor Q13, Q14 or Q9 shorted b. Potentiometer R39 open c. Transistor Q11 or Q12 open d. Transistor Q13 open. Initial symptom: output voltmeter pointer pegs, then output drops to zero e. Transistor Q12 shorted. See "d" for initial symptom.
High Unit Output. Square wave display on oscilloscope (refer to para 6-7)	a. Potentiometer R41, R42 or R43 open b. Transistor Q11 shorted c. Transistor Q9 open d. Potentiometer R43 wiper open
Unit Output goes to Maximum; COARSE VOLTAGE ADJUST has no effect	Potentiometer R41 wiper open
Low Output Voltage	Diode CR24 open

Table 6-3. Voltage-mode Section Troubleshooting.

6-8. CURRENT-MODE SECTION. If tests of both the voltage regulator and voltage-mode sections show that these sections are operating properly, proceed as follows to test current-mode operation:

a. Turn FINE and COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS controls fully counter-clockwise.
b. Connect a 0-1 volt dc voltmeter across the unit output terminals.
c. Make certain properly sequenced three-phase input is available and then set unit circuit breaker to ON.
d. Rotate FINE VOLTAGE ADJJST control until 0.1 volts is indicated on test voltmeter.
e. Open circuit breaker and disconnect test voltmeter. Connect about a two-foot length of No.8 wire across output terminals.
f. Close unit circuit breaker. CURRENT MODE indicator will glow.
g. In steps using small increments, rotate CUR. ADJ. AMPS to 50 A while observing ammeter. Ammeter should read output equal to that set on control.

6-8. (Cont.)

h. If unit does not function as specified above, refer to Table 6-4.

i. Terminate test by setting unit circuit breaker to OFF and by removing terminal shorting wire.

6-9. CALIBRATION.

6-10. The following paragraphs delineate the steps to be followed for complete unit calibration.

6-11. CONTROL-CIRCUIT VOLTAGE REGULATOR. Procedures to calibrate the voltage regulator are identical to those listed under para 6-6.

6-12. VOLTAGE-PROGRAMMING CURRENT. To make the programming current calibration, proceed as follows:

a. Remove unijunction transistors (Q17, Q19 and Q21). Mark each for eventual return to socket from which it was removed.

SYMPTOM		TROUBLE
No Output; CURRENT MODE Indicator glows (refer to para 6-8)	a.	Diode CR22 shorted
	b.	Potentiometer R25 defective; check wiper
	c.	Diode CR23 shorted
Over-current; CURRENT MODE Indicator glows (refer to para 6-8)	a.	Diode CR22 open
	b.	Potentiometer R24 open
Over-current; no indication from CURRENT MODE light	a.	Transistor Q8 shorted
	b.	Transistor Q10 open
No Current Output; no indication from CURRENT MODE light	a.	Transistor Q8 open
	b.	Transistor Q10 shorted
Ammeter indicates maximum output; CURRENT MODE Indicator glows; CUR. ADJ. AMPS has no effect		Defective wiper on potentiometer R24
Current lower than that set on CUR. ADJ. AMPS control (refer to para 6-8); CURRENT MODE light glows		Transistor Q15 shorted
Unit current limiting; no light indication	a.	Burned out lamp
	b.	Open transistor Q15

Table 6-4. Current-Mode Section Troubleshooting.

b. Set COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise. Rotate CUR. ADJ. AMPS control fully clockwise.

c. Connect a milliammeter (0-10 mA range) in series with potentiometer R41 (COARSE VOLTAGE ADJUST). Use clip-on type meter, if available.

d. Apply properly sequenced three-phase input and close unit circuit breaker. Test ammeter should indicate approximately 2 mA. Adjust potentiometer (R39) to obtain specified indication.

e. Set unit circuit breaker to OFF and remove ammeter from reference circuit.

f. Insert each unijunction transistor (Q17, Q19 and Q21) into its respective socket.

6-13. OUTPUT VOLTAGE. With unit hooked up to a properly sequenced three-phase input, proceed as follows to calibrate unit voltage output:

a. Close unit circuit breaker.

b. Rotate COARSE VOLTAGE ADJUST control to obtain a 10 V no-load output.

c. Connect an oscilloscope (.02 V/cm, 10 msec/cm) across output terminals.

d. Apply full load and observe oscilloscope pattern. Position horizontal axis so that a comparison between the peaks may be made. Peaks should be adjusted so that all are within a 20 to 30 mV horizontal band. Use potentiometers R60, R63 and R66.

e. Disconnect oscilloscope and load.

f. Rotate COARSE VOLTAGE ADJUST control fully clockwise. Unit output meter should indicate 20 V. If it does not, adjust potentiometer R39 until output voltage is 20 V.

g. Turn COARSE and FINE VOLTAGE ADJUST controls fully counterclockwise.

h. Connect a differential voltmeter across output terminals. Test voltmeter should indicate 0 ± .05 V. If it does not, adjust potentiometer R43 to bring output to specified value.

i. Disconnect test voltmeter and turn COARSE VOLTAGE ADJUST control fully clockwise. If unit voltmeter does not indicate 20 V; re-adjust potentiometer R39. Repeat "h" and "i" until all values are as specified.

j. Set unit circuit breaker to OFF.

6-14. CURRENT LIMITING. To perform current limiting calibration, proceed as follows:

a. Connect a 0.001 ohm, 250 watt resistor across output terminals.

b. Set COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS controls fully counterclockwise.

c. Rotate FINE VOLTAGE ADJUST control fully clockwise.

d. Connect a differential voltmeter across the 0.001 ohm resistor.

e. Set unit circuit breaker to ON.

f. Rotate CUR. ADJ. AMPS control fully clockwise. Test voltmeter should indicate 0.3 ± .003 V. If it does not, adjust using potentiometer R25.

g. Rotate CUR. ADJ. AMPS control fully counterclockwise. Voltmeter should indicate 0 ± .0005 V. Adjust potentiometer R23 if necessary to bring voltage to within range specified. Repeat step "f" and "g" in sequence until all values are as specified.

h. Set unit circuit breaker to OFF. Remove voltmeter and resistor from across output terminals.

6-15. GAIN ADJUST. To calibrate the gain, proceed as follows:

a. Rotate COARSE VOLTAGE ADJUST and CUR. ADJ. AMPS completely clockwise. Adjust potentiometers R60, R63 and R66 almost fully clockwise.

NOTE

Setting potentiometers (R60, R63, R66) fully clockwise will cause the output to collapse. Rotate slightly counterclockwise if this occurs.

b. Reduce input voltage to low end of input specification. Refer to Tables 1-1 and 1-2.

c. Balance potentiometers R60, R63 and R66 per para 6-13, steps a-d.

d. Check no-load to full-load regulation. Regulation should be between 30 and 50 mV.

e. Readjust R60, R63 and R66 to obtain a load regulation between 15 and 25 mV. Use R60 as the gain adjust and R63 and R66 as the balancing potentiometers. Final resistance readings of R60, R63 and R66 must be between 750 and 1500 ohms.

f. Rebalance ripple voltage per para 6-13, steps a-d. " Glyptal" resistors R60, R63 and R66.

6-16. PERFORMANCE TESTING.

6-17. The following paragraphs outline checks on unit output that may be performed following unit calibration.

6-18. REGULATION AND RIPPLE. Proceed as follows to test line regulation and output ripple following a unit calibration:

a. Apply three-phase low-line voltage to input terminals. Refer to Tables 1-1 and 1-2 for input line specifications.

b. Connect an oscilloscope across output terminals.

c. Turn COARSE VOLTAGE ADJUST control fully clockwise; set CUR. ADJ. AMPS control to right-hand stop.

d. Close unit circuit breaker.

e. Set unit output to 20 V.

f. While slowly increasing input voltage, apply load in small increments until input voltage is at high line and current output is at 275 A. Regulation should be 40 mV and ripple less than or equal to 160 mV.

g. Set unit circuit breaker to OFF. Disconnect oscilloscope.

6-19. TRANSIENT RESPONSE. Test transient response as follows:

a. Rotate CUR. ADJ. AMPS control fully clockwise.

b. Set unit circuit breaker to ON.

c. Connect an oscilloscope across output terminals.

d. Set unit output to 20 V.

e. Apply half load then apply full load. Then go from full load to half load. Maximum output deviation should be 1 volt (typical) and return to steady state (19.8-20.2 V) should occur in 40 msec.

f. Set unit circuit breaker to OFF and disconnect oscilloscope.

6-20. CURRENT REGULATION. To check unit current regulation proceed as follows:

a. Connect a differential voltmeter across resistor R56.

b. Set CUR. ADJ. AMPS control to 30.

c. Apply a 60 A load to unit.

d. Set unit circuit breaker to ON. Differential voltmeter should indicate between 8.6 and 9.0 V. If it does not, adjust using potentiometer (R57). Note output voltage.

e. Set unit circuit breaker to OFF and short circuit the load.

f. Set unit circuit breaker to ON, and rotate CUR. ADJ. AMPS control until output ammeter indicates 275 A.

g. Remove short circuit and adjust load to return output voltage to that noted in step "d".

h. Set unit circuit breaker to OFF and connect a .001 ohm, 250 W resistor in series with the load. Connect the differential voltmeter across the resistor. Set input voltage to low line.

i. Short circuit the load. Differential voltmeter reading should not change more than 0.5 mV.

j. Set unit circuit breaker to OFF and disconnect test voltmeter.

NOTE

"Glyptal" potentiometers R25, R39, R43, R20, R23 and R57.

6-21. THERMAL OVERLOAD. With a 20 volt, no load output, short a set of thermostat terminals. Output should go to zero and THERMAL OVERLOAD indicator should glow. Repeat procedure for each of the other two thermostats.

6-22. PHASE FAILURE. With a 20 volt, no-load output, disconnect an input line. Output drops to zero and PHASE FAILURE indicator glows. Reconnect input line, then repeat test for each of the other two lines.

6-23. PERIODIC SERVICING.

6-24. Periodic servicing of the unit entails only the lubrication of the cooling fans. The intervals at which the fans are to be oiled are a function of both the unit's duty cycle and the ambient temperature. If the unit is operated continuously in high ambients, the fans should be lubricated every 6 months. If, on the other hand, the unit is operated intermittently at room temperatures (20 to 25°C) or below, lubrication need only take place at 12 month periods. For operating conditions between the two duty and temperature extremes, select an interval between 6 and 12 months. The lubricant recommended by Rotron Manufacturing Company, Woodstock, N.Y. is supplied in kit form and may be purchased under Rotron part number 19263.

6-25. To lubricate, remove front panel to expose heat sink mounting screws. Remove cooling fan side panel. Back-off heat sink mounting screws until heat sink is free. Slide heat sink forward to gain access to cooling-fan mounting nuts. Remove nuts and then use above-mentioned kit to lubricate at spot indicated on rotor end face.

SECTION VII
REPLACEMENT PARTS LIST

7-1. INTRODUCTION.

7-2. This section contains a complete unit replacement parts list in Table 7-1. It is keyed to both the schematic diagram (Figure 5-3, immediately following this section) and to Figure 7-1, which shows the physical location of the components.

7-3. MANUFACTURER CODING.

7-4. A manufacturer-coding designator precedes the part number in the MANUFACTURER PART NO. column of Table 7-1.

Designator	Manufacturer
AB	Allen Bradley Company
AC	Allied Control Co., Inc.
AX	Aerovox Corp.
CB	Centralab, Div. of Globe Union Incorporated
EFJ	E.F. Johnson Company
FC	Fairchild Semiconductor
GE	General Electric Co.
HF	Hoffman Electronics
IRC	International Resistance Co.
MA	Motorola Semiconductor Products Inc.
RCA	Radio Corporation of America
RM	Ram Meter Incorporated
RN	Rotron Manufacturing Company
SG	Sage Electronics Corporation
SP	Sprague Electric Company
SR	Sorensen Company
ST	Solitron Devices, Incorporated
WH	Westinghouse Electric Corp.
WL	Ward Leonard Electric Co.

7-6. When ordering parts from Sorensen Company, include manufacturer's part number (if applicable), the Sorensen part number and the unit model number. Address orders to:

Sorensen Company
676 Island Pond Road
Manchester, N.H. 03103

REF. DES.	DESCRIPTION	SORENSEN PART NO.	MANUFACTURER PART NO.
B1, 2, 3	FAN	91-1000-2	RN, MUFFIN
C1, 3, 5	CAP., 0.1 μF, 600 V	24-2410-13	AX
C2, 4, 6	CAP., 0.1 μf, 200 V	24-2409-13	AX
C7	CAP., 115,000 μF, 25 V	24-2549	GE, 86F145S
C8,21, 22, 23	CAP., 0.22 μF, 200 V	24-2409-15	AX
C9	CAP., 250 μF, 50 V	24-2287-8	SP
C10, 14, 19	CAP., 25 μF, 25V	24-2286-4	SP
C11	CAP., 50 μF, 25 V	24-2286-5	SP
C12	CAP., 20 μF, 15 V	24-2278-10	SP
C13, 17	CAP., 100 μF, 15 V	24-2278-15	SP
C15	CAP., 35 μF, 25 V	24-2279-11	SP
C16, 20	CAP., .01 μF, 200 V	24-2409-7	AX
C18	CAP., 4 μF, 25 V	24-2279-4	SP
C24, 25, 26	CAP., 75 μF, 75 V	24-2457-2	SP
C27	CAP., 50 μF, 50 V	24-2280-12	SP
C28, 29, 30	CAP., 0.33 μF, 400 V	24-2411-16	AX
C31, 32, 33, 34, 35, 36	CAP., .05 μF, 500 V	24-2010	CB, .05 TYPE I.D.
C37, 38	CAP., 1.0 μF, 200 V	24-2409-19	AX
C39, 40, 41	CAP., 2.0 μF, 330 V AC	24-369	SR
CB1	CIRCUIT BREAKER	92-346	
CR1, 3, 5	RECT.	26-1047	GE, C145E *
CR2, 4, 6	RECT.	26-1024	GE, 1N1189
CR7, 9, 11	RECT.	26-1025-4	WH, 508C401HO2
CR8, 10, 12	RECT.	26-1025-3	WH,508C400HO2
CR13, 14, 15, 18, 19,25,26 22	RECT.	26-1017	SR, RD9119
CR16, 17, 33, 23, 34, 35, 36	RECT.	26-158-1	ST, CER68
CR20	RECT.	26-211	MA, 1N751
CR24	RECT.	26-233	MA, 1N746
CR28, 29, 30	RECT.	26-244	ST, 1R20A
CR31, 32, 33	RECT.	26-158-2	ST, CER69
CR27	RECT.	26-206	MA, 1N753
DS1	PILOT LIGHT	42-315	GE, 1829
XDS 1, 4	HOLDER (AMBER)	43-322	EFJ, 147-1142-4
DS2	PILOT LIGHT	42-341	GE, 1302
XDS2	HOLDER (GREEN)	43-341	EFJ, 147-1142-3
DS3	PILOT LIGHT	42-301	GE, NE51
XDS3	HOLDER (RED)	42-383	EFJ, 147-1143-2
DS4	PILOT LIGHT	42-344	GE, 1815
K1, 2	RELAY	92-924	AC, T154X-881 (1K SPECIAL)
L1, 2, 3	RFI CHOKE	127-1748	SR
L4	FILTER CHOKE	127-1759	SR
M1	METER, 300 A, 50 mV	94-433-18	SR
M2	METER, 25 V	94-549-13	SR

* Early models utilize a GE C152E45X for CR 1, 3, 5. Before ordering, check number of part in unit. If it is an early model SCR, then order from Sorensen specifying both the Sorensen and GE part numbers (26-1047 and C 152E45X, respectively).

Table 7-1. Replacement Parts List, Model DCR20-250A

REF. DES.	DESCRIPTION	SORENSEN PART NO.	MANUFACTURER PART NO.
Q1	TRANSISTOR	18-146	SR, RT9338
Q2	TRANSISTOR	18-142	RCA, 40312
Q3, 4, 5, 6, 14	TRANSISTOR	18-144	FC, FSC3641
Q7, 8, 9, 10, 11, 16, 18, 20	TRANSISTOR	18-143	FC, 2N3638
Q12, 13	TRANSISTOR	18-125-2	SR
Q15	TRANSISTOR	18-115	GE, 2N697
Q17, 19, 21	TRANSISTOR	18-153	GE, 2N2647
R1, 2, 3	RES., 0.16 OHM, 175 W	27-1071	WL, 6" W CORE
R4, 6, 8	RES., 33 OHM, 2 W	27-335	AB, HB3301
R10	RES., 3 OHM, 225 W	27-1073	WL
R11	RES, 2 OHM 225 W	27-1072	WL
R12	SHUNT, 300 A	94-013	RM
R13	RES., 1.3 mOHM	190-3600	SR
R14, 28	RES., 100 OHM, 1/2 W	27-173	AB, EB1011
R15	RES., 680 OHM, 2 W	27-360	AB, HB6811
R16	RES., 1.2 kOHM, 1/2 W	27-150	AB, EB1225
R17, 18, 19, 29, 38	RES., 1 kOHM, 1/2 W	27-103	AB, EB1021
R20	POT., 1 kOHM, 2 W	29-406	SR
R21	RES., 680 OHM, 1/2 W	27-156	AB, EB6811
R22, 47	RES., 2.2 kOHM, 1/2 W	27-152	AB, EB2221
R23	POT., 500 OHM, 2 W	29-450	SR
R24, 42	POT., 150 OHM, 2 W	29-391	SR
R25	POT., 10 kOHM, 2 W	29-493	SR
R26	RES., 3.92 kOHM, 1/2 W	28-1145	IRC
R27	RES., 221 OHM, 1/2 W	28-1188	IRC
R30, 45	RES., 4.7 kOHM, 1/2 W	27-107	AB, EB4721
R31	RES., 681 OHM, 1/4 W, ± 1%	28-1224	IRC
R32	RES., 332 OHM, 1/4 W, ± 1%	28-1223	IRC
R33	RES., 10 kOHM, 1/4 W, ± 1%	28-1226	IRC
R34, 36, 37	RES., 330 OHM, 1/2 W	27-102	AB, EB3311
R35, 44	RES., 470 OHM, 1/2 W	27-166	AB, EB4711
R39	POT., 2 kOHM, 2 W	29-407	SR
R40	RES., 475 OHM, 1/4 W	28-1166	IRC
R41	POT., 3 kOHM, 2 W	29-408	SR
R43	POT., 4 kOHM, 2 W	29-475	SR
R46	RES., 68 kOHM, 1/2 W	27-143	AB, EB6831
R48	RES., 6.8 kOHM, 1/2 W	27-185	AB, EB6821
R49	RES., 182 OHM, 1/4 W, ± 1%	28-1222	IRC
R50	RES, 2.7 kOHM, 1/2 W	27-174	AB, EB2721
R51	RES., 2 kOHM, 5 W	28-1200	SG, 1500S2000-5
R52	RES., 900 OHM, 3 W	28-1153	SG, 1400S900-5
R53	RES., 2 kOHM, 1/4 W, ± 1%	28-1225	IRC
R54	RES., 121 OHM, 1/4 W., ± 1%	28-1221	IRC
R55, 71	RES., 5.1 kOHM, 2 W	27-344	AB, HB5125
R56	RES., 220 OHM, 1 W	27-205	AB, GB2211
R57	POT., 50 OHM, 2 W	29-467	SR
R58	RES., 22 OHM, 1/2 W	27-153	AB, EB2201
R59, 62, 65	RES., 6.8 kOHM, 3 W	27-398-18	WL
R60, 63, 66	POT., 2 kOHM, 2 W	29-494	SR
R61, 64, 67	RES., 390 OHM, 1/2 W	27-1109	AB, EB3911
R68, 69, 70	RES., 3.3 kOHM, 3 W	27-398-10	WL
R72	RES., 220 OHM, 1/2 W	27-101	AB, EB2211
S1, 2	THERMOSTAT, 250°F	92-516	SR
S3	THERMOSTAT	91-1286	SR
T1, 2, 3	TRANSFORMER	126-2832	SR
T4	TRANSFORMER, CONTROL	126-2830	SR
T5	TRANSFORMER, FAN	126-2829	SR
T6, 7, 8	TRANSFORMER, PULSE	126-2632	SR

Table 7-1. Replacement Parts List, Model DCR20-250A (Cont.)

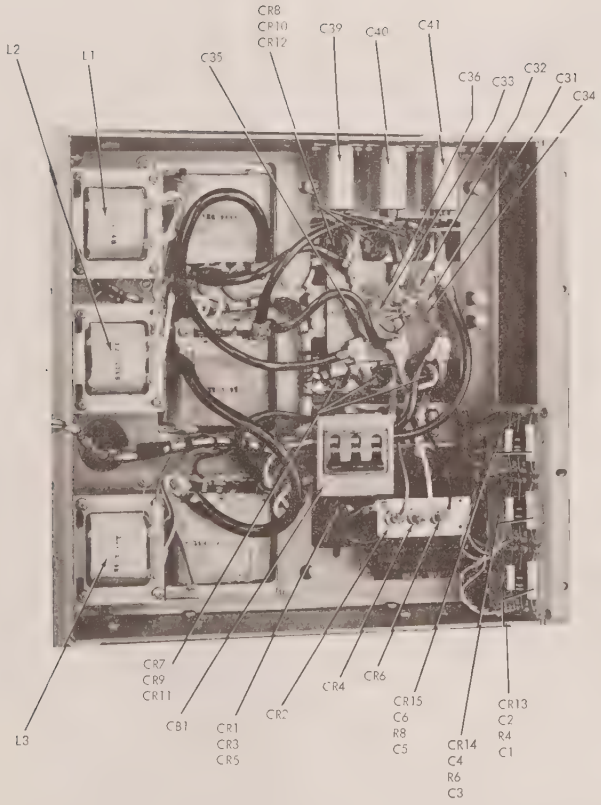


Figure 7-1A. Front View, Panel Removed.

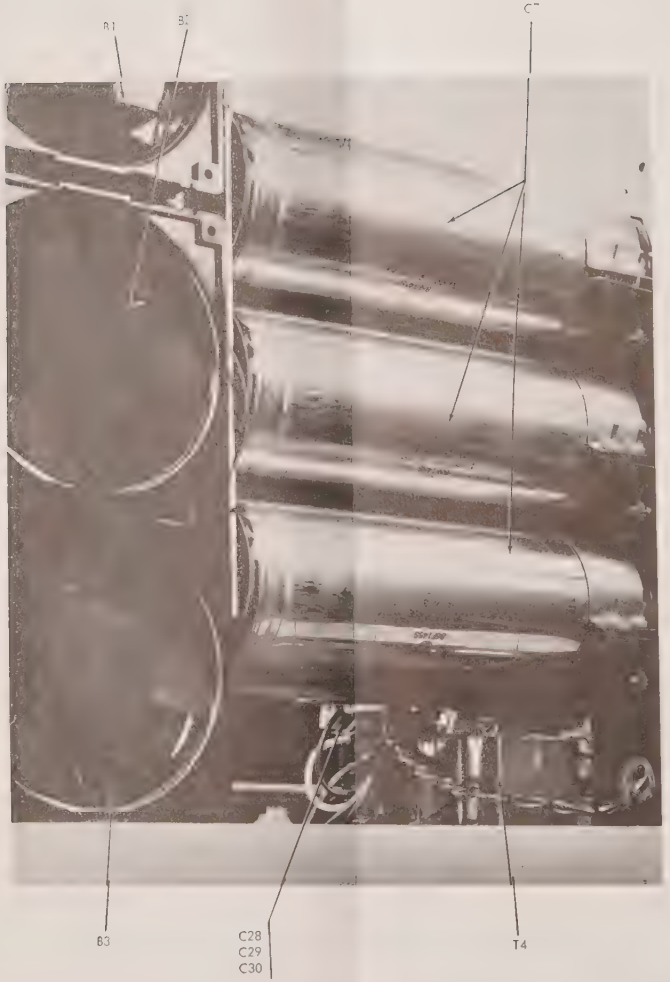


Figure 7-1B. Right Side of Chassis, Panel Removed

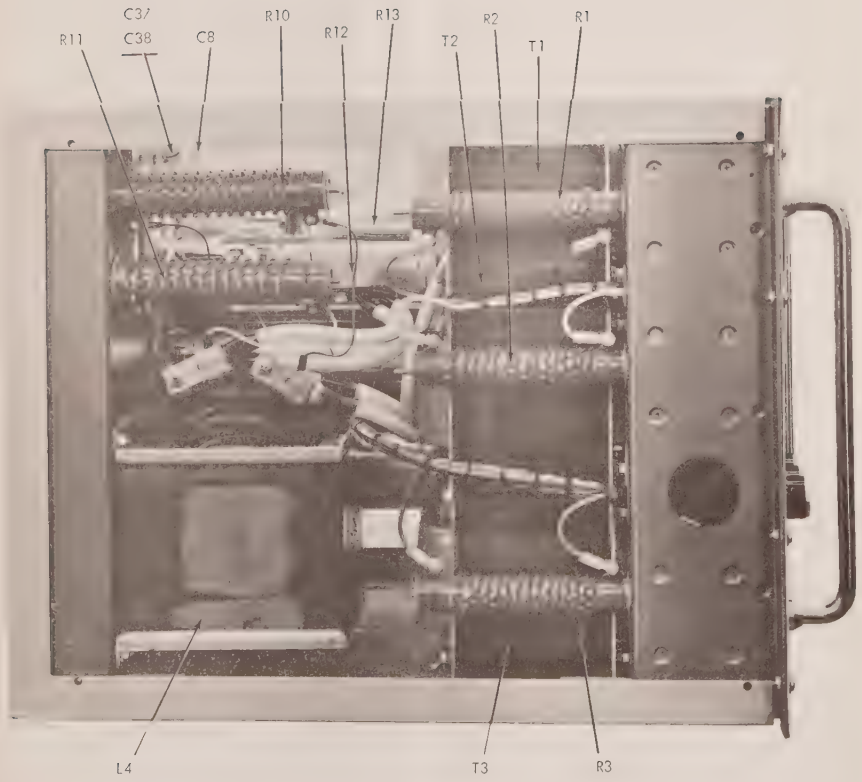


Figure 7-1C. Left Side of Chassis, Panel Removed

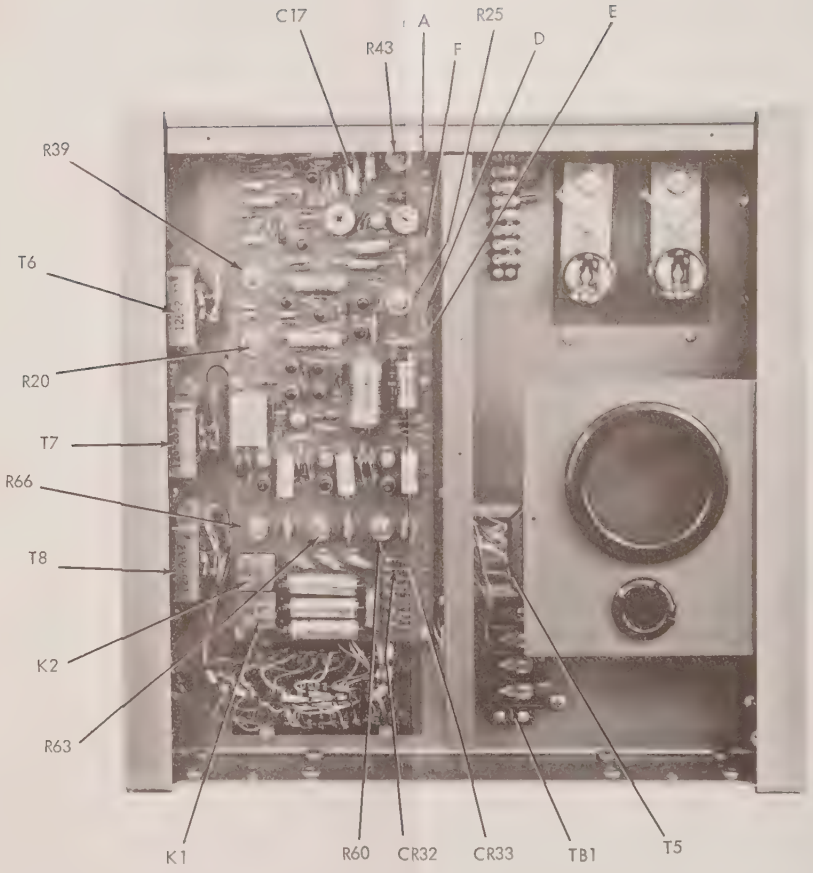


Figure 7-1D. Rear View, Panel Removed

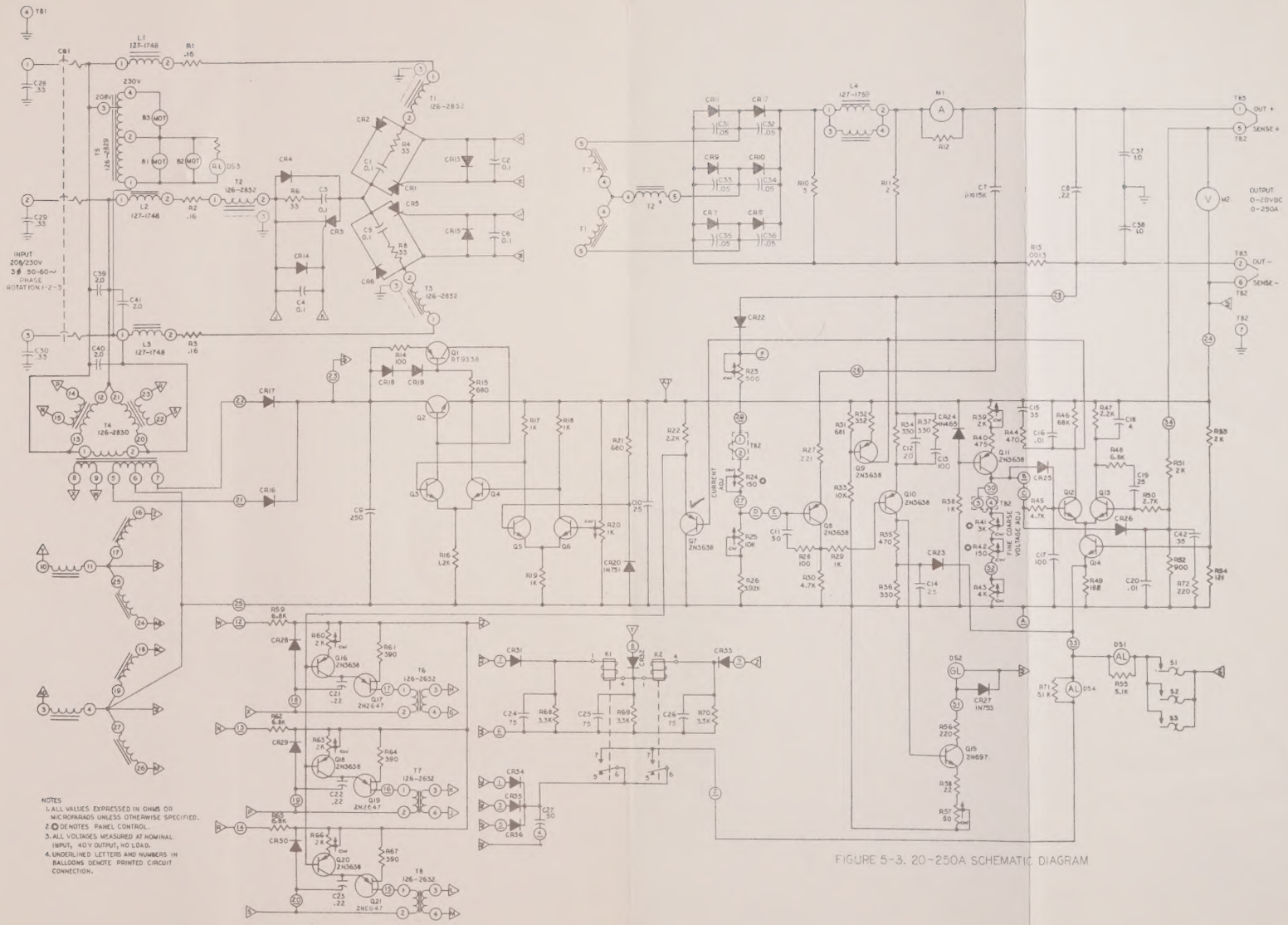


FIGURE 5-3. 20-250A SCHEMATIC DIAGRAM

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POWER SUPPLIES

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